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(54) Title: INCREASED STARCH CONTENT IN PLANTS

DNA ATGGTTAGTTTAGAGAAGACGATCACTTAATGTTGGCCGCGACGTGCCATTGAATCT
Protein M V S L E K N D H L H L A R Q L P L K S

61 GTTGCCTGATCTGGCGGAGGACGTGGTACCCGCTGAAGGATTAACCAATAGCGA
Y A L I L A G G R G T R L K D L T N K R

121 GCAAAACCGCGCTACACTTCGGCGGTAAGTTCGCGATTATCGACTTTCGGCTGTCTAAC
A K P A V H F G G K F R I I D F A L S N

181 TGCATCAACTCCGGGATCCGTCGTATGGGCGTGATCAACCGATACCGTCCACACTCTG
C I N S G I R R H G V I T Q Y Q S H T L

241 GTGCAGCATTACGCGCGCTGTGCTATTCTTCAATGAGAATGAGCAGTTTGTGAT
V Q H I Q R G V S F F N E E M N E F V D

301 CTCTGCCGACGACGAGAGATGAAGGGGAACTGGTATCCGGGACCGCAGATGCG
L L P A Q Q R N K G E N V Y R G T A D A

361 GTCAACCAAACTCGACATTATCCGCTTATAAGCGGAATACGTGGTATCCTGGCG
V T Q N L D I J R R Y K A E Y V V I L A

421 GCGGACCATATCTACAAGCAAGACTCGCGTATGCTTATCGATCACGTCGAAAAGGT
G D H I Y K D D Y S R H L I D H V E K G

481 GTACGTTGTACGTTGTTGTATGCCAGTACCGATTGAAGAGCGCTCCGCAATTGGCGTT
V R C T V V C H P V P I E E A S A F G V

541 ATGGCGGTTGATGAGAAGCAATAAATCTGATTCGTGAAAACCTCTGAACCGCGG
H A V D E N D K T I E F V E K P A N P P

601 TCAATGCCGACGATCCGAGCAATCTCTGGCGAGTATGGTATCTACGTTTTCAGCGC
S M P N D P S K S L A S H G I Y V F D Q

661 GACTATCTGTATGAAGTCTGGAAGAAGACGATCGCGATGAGAAGCTCCAGCCAGACTTT
D Y L Y E L L E E D R D E N S S H D F

721 GCGAAGATTGATCCCAAGATCACCGAGCGCGTGGCTATGGGACCGGTTCGCG
G K D L I P K I T E A G L A Y A H P F P

781 CTCTCTTGCCTACAATCCGACCGGATGCCGAGCGCTACTGGCGGATGTGGGTACGCTG
L S C V Q S D P D A E P Y V R D V G T L

841 GAAGCTTACTGGAAAGCAACCTCGATCTGGCTCTGTGGTGGCGAAGCTGATATGTAC
E A Y V K A N L D L A S V V P E L D H Y

901 GATCGAATTGGCCAATTGCGACCTACAATGATCATTACCGCCAGCAATTCGTGAG
D R N V P I R T Y N E S L P P A K F V Q

961 GATCGCTCCGTAAGCCAGCGGATGACCTTAACCTACTGGTTCGAGCGGTGTGTGATC
D R S G S H G M T L N S L V S D G C V I

1021 TCCGTTCCGTTGGTGGTGCAGTCCGTTCTGTCTCGCGCGTTCGCGTGAATTCATTCTGC
S G S V V V Q S V L F S R V R V N S F C

1081 AACATTGATTCGCCGCTATTGTTACCGGAAGTATGGTAGTCTGCTGCTGCTGCGC
N I D S A V L L P E V V V G R S C R L R

1141 CGCTGCTCATGATCGTCTGTGTATTCCGGAAGCATGGTATTGGTGAAGAACGCA
R C V I D R A C V I P E G H V I G E N A

1201 GAGGAAGATGCAGTCTGTTTCTATCGTTGAGAGAAGCATCTGCTGTAACGCGGAA
E E D A R R F Y R S E E G I V L V T R E

1261 ATGCTACGGAAGTTAGGCGATAACAGAGGAGCATAA
M L R K L G H K Q E R X

(57) Abstract

Transformed plant cells which have increased starch content are disclosed. Also disclosed are whole plants comprising plant cells which express CTP/ADP glucose pyrophosphorylase genes.

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INCREASED STARCH CONTENT IN PLANTS

5 This is a continuation-in-part of a co-pending U.S. application having serial No. 07/539,763, filed on June 18, 1990 and entitled "Increased Starch Content in Plants".

10 Recent advances in genetic engineering have provided the requisite tools to transform plants to contain foreign genes. It is now possible to produce plants which have unique characteristics of agronomic and crop processing importance. Certainly, one such advantageous trait is enhanced starch content and quality in various crop plants.

15 Starch is a polysaccharide primarily composed of glucose units connected by alpha 1-4 and alpha 1-6 linkages. It is found in plant cells as water-insoluble grains or granules. During photosynthesis, starch is produced and stored in chloroplasts. Starch is also synthesized in roots and storage organs such as tubers and seeds. In these non-photosynthetic tissues, the starch is found in a form of plastids called amyloplasts. As in the chloroplasts, starch is stored in the amyloplasts as starch granules. The size of the granules varies depending on the plant species.

20 Starch is actually composed of amylose and amylopectin, two distinct types of glucose polymers. Amylose is composed primarily of linear chains of alpha 1-4 linked glucose molecules. On average, amylose has a chain length of about 1000 glucose molecules. Amylopectin contains shorter chains linked together with alpha 1-6 linkages. On average, amylopectin has a chain length of about 20-25 glucose molecules.

30 Until recently, there was controversy in the literature as to whether ADPglucose or UDPglucose was the substrate for starch synthesis. With the isolation of *Arabidopsis* mutants lacking ADPglucose pyrophosphorylase it is now accepted that

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plants use ADPglucose as the substrate for starch synthesis. There are three steps in the synthesis of starch. All these reactions take place within the chloroplasts or amyloplasts. In the first step, ADPglucose is produced from glucose-1-phosphate and ATP by ADPglucose pyrophosphorylase (EC 2.7.7.27). In the second step, ADPglucose is used by starch synthase (EC 2.4.1.21) to form linear chains of starch containing the α , 1-4 linkage. In the third step, the branching enzyme(s) (EC 2.4.1.18) introduce alpha 1-6 linkages to produce the amylopectin molecule.

The controlling step in the synthesis of starch in plants has been a topic of dispute. Although synthesis of ADPglucose by ADPglucose pyrophosphorylase has been proposed to be the controlling step in starch biosynthesis, this has not been proved. In fact, European Patent Application publication number 0368506 A2, which concerns ADPglucose pyrophosphorylase, questions the role of the enzyme as the rate limiting step in starch biosynthesis. An argument against ADPglucose pyrophosphorylase being the controlling enzyme can be made from the results with an *Arabidopsis* mutant (Lin, 1988a,b). This mutant, TL46, was found to contain only about 5% of the ADPglucose pyrophosphorylase activity compared to the wild type plants. However, TL46 plants still produced about 40% of the wild type starch levels. If ADPglucose pyrophosphorylase is the rate limiting enzyme, one would have expected a 95% reduction in enzyme activity to produce more than a 60% reduction in starch accumulation. Similarly, the *in vitro* measurements on extractable activities suggest this enzyme can only be rate limiting if its *in vivo* activity is substantially inhibited by the allosteric regulators of the enzyme activity.

SUMMARY OF THE INVENTION

5 The present invention provides structural DNA constructs which encode an ADPglucose pyrophosphorylase (ADPGPP) enzyme and which are useful in producing enhanced starch content in plants. It is also demonstrated that the ADPGPP enzyme activity in plant cells and tissues is a controlling step in starch biosynthesis.

10 In accomplishing the foregoing, there is provided, in accordance with one aspect of the present invention, a method of producing genetically transformed plants which have elevated starch content, comprising the steps of:

- 15 (a) inserting into the genome of a plant cell a recombinant, double-stranded DNA molecule comprising
- 20 (i) a promoter which functions in plants to cause the production of an RNA sequence in target plant tissues,
- (ii) a structural DNA sequence that causes the production of an RNA sequence which encodes a fusion polypeptide comprising an amino-terminal plastid transit peptide and an ADPglucose pyrophosphorylase enzyme,
- 25 (iii) a 3' non-translated DNA sequence which functions in plant cells to cause transcriptional termination and the addition of polyadenylated nucleotides to the 3' end of the RNA sequence;
- 30 (b) obtaining transformed plant cells; and

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- (c) regenerating from the transformed plant cells genetically transformed plants which have an elevated starch content.

5 In accordance with another aspect of the present invention, there is provided a recombinant, double-stranded DNA molecule comprising in sequence:

- (a) a promoter which functions in plants to cause the production of an RNA sequence in target plant tissues;
- 10 (b) a structural DNA sequence that causes the production of an RNA sequence which encodes a fusion polypeptide comprising an amino-terminal plastid transit peptide and an ADPglucose pyrophosphorylase enzyme; and
- 15 (c) a 3' non-translated region which functions in plant cells to cause transcriptional termination and the addition of polyadenylated nucleotides to the 3' end of the RNA sequence, said promoter being heterologous with respect to the structural
- 20 DNA.

There has also been provided, in accordance with another aspect of the present invention, bacterial and transformed plant cells that contain, respectively, DNA comprised of the above-mentioned elements (a), (b) and (c).

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In accordance with yet another aspect of the present invention, differentiated plants are provided that have increased starch content.

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BRIEF DESCRIPTION OF THE DRAWINGS

5 Figure 1 shows the nucleotide sequence (SEQ ID NO:1) and deduced amino acid sequence (SEQ ID NO:2) for the ADPglucose pyrophosphorylase (*glgC*) gene from *E. coli*.

 Figure 2 shows the nucleotide sequence (SEQ ID NO:3) and deduced amino acid sequence (SEQ ID NO:4) for the mutant ADPglucose pyrophosphorylase (*glgC16*) gene from *E. coli*.

10 Figure 3 shows the nucleotide sequence (SEQ ID NO:5) and corresponding amino acid sequence (SEQ ID NO:6) for the modified chloroplast transit peptide from the ssRUBISCO 1A gene from *Arabidopsis thaliana*.

15 Figure 4 shows a plasmid map for plant transformation vector pMON530.

 Figure 5 shows the nucleotide sequence (SEQ ID NO:7) and the corresponding amino acid sequence (SEQ ID NO:8) of the assembled small subunit ADPglucose pyrophosphorylase gene of potato.

20 Figure 6 shows the near full length nucleotide sequence (SEQ ID NO:9) and the corresponding amino acid sequence (SEQ ID NO:10) of the almost complete large subunit ADPglucose pyrophosphorylase gene of potato.

25 Figure 7 shows a plasmid map for plant transformation vector pMON20113.

 Figure 8 shows a plasmid map for plant transformation vector pMON16938.

 Figure 9 shows a plasmid map for plant transformation vector pMON977.

30 Figure 10 shows a plasmid map for plant transformation vector pMON16950.

Figure 11 shows a plasmid map for plant transformation vector pMON10098.

DETAILED DESCRIPTION OF THE INVENTION

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The expression of a plant gene which exists in double-stranded DNA form involves transcription of messenger RNA (mRNA) from one strand of the DNA by RNA polymerase enzyme, and the subsequent processing of the mRNA primary transcript inside the nucleus. This processing involves a 3' non-translated region which adds polyadenylate nucleotides to the 3' end of the RNA.

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Transcription of DNA into mRNA is regulated by a region of DNA usually referred to as the "promoter." The promoter region contains a sequence of bases that signals RNA polymerase to associate with the DNA, and to initiate the transcription of mRNA using one of the DNA strands as a template to make a corresponding complimentary strand of RNA.

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A number of promoters which are active in plant cells have been described in the literature. These include the nopaline synthase (NOS) and octopine synthase (OCS) promoters (which are carried on tumor-inducing plasmids of *Agrobacterium tumefaciens*), the caulimovirus promoters such as the cauliflower mosaic virus (CaMV) 19S and 35S and the figwort mosaic virus 35S-promoters, the light-inducible promoter from the small subunit of ribulose-1,5-bis-phosphate carboxylase (ssRUBISCO, a very abundant plant polypeptide), and the chlorophyll a/b binding protein gene promoter, etc. All of these promoters have been used to create various types of DNA

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constructs which have been expressed in plants; see, e.g., PCT publication WO 84/02913 (Rogers et al., Monsanto).

5 Promoters which are known or are found to cause transcription of RNA in plant cells can be used in the present invention. Such promoters may be obtained from a variety of sources such as plants and plant viruses and include, but are not limited to, the enhanced CaMV35S promoter and promoters isolated from plant genes such as ssRUBISCO genes. As
10 described below, it is preferred that the particular promoter selected should be capable of causing sufficient expression to result in the production of an effective amount of ADPglucose pyrophosphorylase enzyme to cause the desired increase in starch content. In addition, it is preferred to bring about
15 expression of the ADPGPP gene in specific tissues of the plant such as leaf, root, tuber, seed, fruit, etc. and the promoter chosen should have the desired tissue and developmental specificity. Those skilled in the art will recognize that the amount of ADPglucose pyrophosphorylase needed to induce the
20 desired increase in starch content may vary with the type of plant and furthermore that too much ADPglucose pyrophosphorylase activity may be deleterious to the plant. Therefore, promoter function should be optimized by selecting a promoter with the desired tissue expression capabilities and
25 approximate promoter strength and selecting a transformant which produces the desired ADPglucose pyrophosphorylase activity in the target tissues. This selection approach from the pool of transformants is routinely employed in expression of heterologous structural genes in plants since there is variation
30 between transformants containing the same heterologous gene due to the site of gene insertion within the plant genome. (Commonly referred to as "position effect").

5 It is preferred that the promoters utilized in the double-stranded DNA molecules of the present invention have relatively high expression in tissues where the increased starch content is desired, such as the tuber of the potato plant and the fruit of tomato. In potato, a particularly preferred promoter in this regard is the patatin promoter described herein in greater detail in the accompanying examples. Expression of the double-stranded DNA molecules of the present invention by a
10 constitutive promoter, expressing the DNA molecule in all or most of the tissues of the plant, will be rarely preferred and may, in some instances, be detrimental to plant growth.

The class I patatin promoter, used in this study to express the *E. coli* ADPGPP, has been shown to be both highly
15 active and tuber-specific (Bevan et al., 1986; Jefferson et al., 1990). A number of other genes with tuber-specific or enhanced expression are known, including the potato tuber ADPGPP genes (Muller et al., 1990), sucrose synthase (Salanoubat and Belliard, 1987, 1989), the major tuber proteins including the 22 kd protein complexes and proteinase inhibitors (Hannapel, 1990),
20 and the other class I and II patatins (Rocha-Sosa et al., 1989; Mignery et al., 1988).

In addition to the endogenous plant ADPglucose pyrophosphorylase promoters, other promoters can also be used to express an ADPglucose pyrophosphorylase gene in specific
25 tissues, such as leaves, seeds or fruits. β -conglycinin (also known as the 7S protein) is one of the major storage proteins in soybean (*Glycine max*) (Tierney, 1987). The promoter for β -conglycinin could be used to over-express the *E. coli*, or any other, ADPglucose pyrophosphorylase gene, specifically in
30 seeds, which would lead to an increase in the starch content of the seeds. The β -subunit of β -conglycinin has been expressed,

using its endogenous promoter, in the seeds of transgenic petunia and tobacco, showing that the promoter functions in a seed-specific manner in other plants (Bray, 1987).

5 The zeins are a group of storage proteins found in maize endosperm. Genomic clones for zein genes have been isolated (Pedersen, 1982), and the promoters from these clones could also be used to express an ADPglucose pyrophosphorylase gene in the seeds of maize and other plants.

10 The starch content of tomato fruit can be increased by expressing an ADPglucose pyrophosphorylase gene behind a fruit specific promoter. The promoter from the 2A11 genomic clone (Pear, 1989) or the E8 promoter (Deikman, 1988) would express the ADPglucose pyrophosphorylase in tomato fruits. In
15 addition, novel fruit specific promoters exhibiting high and specific expression during the development of the tomato fruit have been isolated. A differential screening approach utilizing a tomato fruit cDNA library was used to identify suitable cDNA clones that expressed specifically in green fruit. cDNA probes
20 prepared from mRNA extracted from fruit at early and late developing stages, from combined leaf+stem tissue, and from root tissue of the tomato plant were used. Clones that expressed abundantly in green fruit and that showed no detectable expression in leaves were identified. Genomic Southern
25 analysis indicated a small (1-2) gene copy number. The promoters for these cDNA clones were then isolated by screening a tomato genomic clone bank. The expression pattern of these promoters is confirmed by fusion to the β -glucuronidase (GUS) gene and by following the expression of the GUS enzyme during
30 development in transgenic fruit. Promoters that exhibit expression in most cells of the fruit are then fused to the CTP-

glgC16 and other glgC alleles or the ADPGPP genes derived from either algae or plants.

5 The starch content of root tissue can be increased by expressing an ADPglucose pyrophosphorylase gene behind a root specific promoter. The promoter from the acid chitinase gene (Samac et al., 1990) would express the ADPglucose pyrophosphorylase in root tissue. Expression in root tissue could also be accomplished by utilizing the root specific subdomains of the CaMV35S promoter that have been identified. (Benfey et al., 10 1989). The starch content of leaf tissue can be increased by expressing the ADPglucose pyrophosphorylase gene (e.g. glgC gene) using a leaf active promoter such as ssRUBISCO promoter or chlorophyll a/b binding protein gene promoter.

15 The RNA produced by a DNA construct of the present invention also contains a 5' non-translated leader sequence. This sequence can be derived from the promoter selected to express the gene, and can be specifically modified so as to increase translation of the mRNA. The 5' non-translated regions can also be obtained from viral RNAs, from suitable eukaryotic genes, or from a synthetic gene sequence. The 20 present invention is not limited to constructs, as presented in the following examples, wherein the non-translated region is derived from the 5' non-translated sequence that accompanies the promoter sequence. Rather, the non-translated leader 25 sequence can be derived from an unrelated promoter or coding sequence as discussed above.

30 The DNA constructs of the present invention also contain a structural coding sequence in double-stranded DNA form, which encodes a fusion polypeptide comprising an amino-terminal plastid transit peptide and an ADPglucose pyrophosphorylase enzyme. The ADPglucose pyrophospho-

rylase enzyme utilized in the present invention is preferably subject to reduced allosteric control in plants. Such an unregulated ADPglucose pyrophosphorylase enzyme may be selected from known enzymes which exhibit unregulated enzymatic activity or can be produced by mutagenesis of native bacterial, or algal or plant ADPglucose pyrophosphorylase enzymes as discussed in greater detail hereinafter. In some instances, the substantial differences in the nature of regulators modulating the activity of the wild type ADPglucose pyrophosphorylase (ADPGPP) enzyme permits the use of the wild type gene itself; in these instances, the concentration of the regulators within plant organelles will facilitate elicitation of significant ADPGPP enzyme activity.

Bacterial ADPglucose Pyrophosphorylases

The *E. coli* ADPglucose pyrophosphorylase has been well characterized as a tightly regulated enzyme. The activator fructose 1,6-bisphosphate has been shown to activate the enzyme by increasing its V_{max} , and by increasing the affinity of the enzyme for its substrates (Preiss, 1966 and Gentner, 1967). In addition, fructose 1,6-bisphosphate (FBP) also modulates the sensitivity of the enzyme to the inhibitors adenosine-5'-monophosphate (AMP) and inorganic phosphate (P_i) (Gentner, 1968).

In 1981, the *E. coli* K12 ADPglucose pyrophosphorylase gene (*glg C*), along with the genes for glycogen synthase and branching enzyme, were cloned, and the resulting plasmid was named pOP12 (Okita, 1981). The *glg C* gene, which was sequenced in 1983, contains 1293 bp (SEQ ID NO:1) and encodes 431 amino acids (SEQ ID NO:2) with a deduced molecular weight of 48,762 is shown in Figure 1 (Baecker, 1983).

The *glg C16* gene was generated by chemically mutagenizing *E. coli* K12 strain PA 601 with N-methyl-N'-nitrosoguanidine (Cattaneo, 1969 and Creuzet-Sigal, 1972). Glycogen biosynthetic mutants were detected by iodine staining of mutagenized colonies. The *glg C16* mutant was found to accumulate up to 48% glycogen during the stationary phase, compared to 20% glycogen in the parent strain. When the kinetics of the *glg C16* ADPglucose pyrophosphorylase were compared to the parent, it was found that the *glg C16* ADPglucose pyrophosphorylase had a higher affinity for ADPglucose in the absence of the activator, Fructose 1,6-bisphosphate (FBP), and the concentration of FBP needed for half-maximal activation of the enzyme was decreased in *glg C16*. The inhibition of the ADPglucose pyrophosphorylase activity in *glg C16* by 5'-AMP (AMP) was also reduced.

The *glg C16* gene from *E. coli* K-12 618 has been cloned (Leung, 1986). Two clones, with opposite orientation, were obtained. These clones, pEBL1 and pEBL3, contained both the *glg C16* and the *glg B* (branching enzyme) genes. Both plasmids were transformed into *E. coli* mutant strains that lacked ADPglucose pyrophosphorylase activity. The *E. coli* K-12 G6MD3 is missing the *glg* genes, while the *E. coli* B strain, AC70R1-504, has a defective ADPglucose pyrophosphorylase gene and is derepressed five- to seven-fold for the other glycogen biosynthetic activities. Both plasmids, pEBL1 and pEBL3, produced ADPglucose pyrophosphorylase activity in both mutant strains. The cloned ADPglucose pyrophosphorylase was partially purified from *E. coli* strain AC70R1 transformed with the pEBL3 plasmid. This enzyme was kinetically compared to partially purified ADPglucose pyrophosphorylase from the original mutant strain (*E. coli* K-12 618), and to the partially purified

ADPglucose pyrophosphorylase from *E. coli* K-12 strain 356, which is the wild type parent strain of strain 618. The wild type and mutant enzymes were compared in their levels of activation and inhibition. The parent strain 356 ADPglucose pyrophosphorylase was activated about 45-fold with fructose 1,6-bisphosphate. The sigmoidal activation curve had a Hill slope of 1.7, and 50% maximal stimulation was seen at 62 μ M FBP. The mutant strain 618 ADPglucose pyrophosphorylase was more active in the absence of FBP, and was activated only 1.8- to 2-fold with FBP. The activation curve for the 618 ADPglucose pyrophosphorylase was hyperbolic with a Hill slope of 1.0, and 50% of maximal stimulation was seen at 15 \pm 3.1 μ M. The enzyme expressed from the pEBL3 plasmid gave the same FBP kinetic constants as the ADPglucose pyrophosphorylase from mutant strain 618.

The DNA sequence of the *glg C16* gene is now known (SEQ ID NO:3) (Kumar, 1989). Referring to Figure 2, when the *glg C16* deduced amino acid sequence (SEQ ID NO:4) was compared to the nonisogenic *E. coli* K-12 3000, two amino acid changes are noted. The two changes are Lys 296 to Glu, and Gly 336 to Asp.

A number of other ADPglucose pyrophosphorylase mutants have been found in *E. coli*. The expression of any of these or other bacterial ADPglucose pyrophosphorylase wild type or mutants could also be used to increase starch production in plants.

E. coli K12 strain 6047 (*glg C47*) accumulates about the same amount of glycogen during stationary phase as does strain 618 (*glg C16*). Strain 6047, like 618, shows a higher apparent affinity for FBP, and more activity in the absence of FBP. However, the enzyme from strain 6047 is reportedly more

sensitive to inhibition by AMP compared to the enzyme from strain 618 (Latil-Damotte, 1977).

5 The *E. coli* B mutant, SG5, has a higher affinity for its allosteric activators and a lower affinity for its allosteric inhibitor, when compared to its parent strain (Govons, 1969; Govons, 1973 and Preiss, 1973). These changes alone make the enzyme more active under physiological conditions, and this causes the bacteria to accumulate two to three times as much
10 glycogen as the parent strain. The mutant ADPglucose pyrophosphorylase from SG5, like the wild type, exists as a homotetramer. Unlike the wild type, however, FBP causes the mutant enzyme to form higher weight oligomers (Carlson, 1976).

15 The ADPglucose pyrophosphorylase from the *E. coli* B mutant strain CL1136-504 also has a higher apparent affinity for activators and a lower apparent affinity for inhibitors (Kappel, 1981 and Preiss, 1973). This mutant will accumulate three- to four-fold more glycogen than the wild type *E. coli*. Under activated conditions, the purified CL1136-504 enzyme and the
20 wild type (AC70R1) enzyme have comparable specific activities. However, in the absence of any activators, the CL1136-504 enzyme is highly active, unlike the wild type enzyme.

25 The *glg C* gene from *Salmonella typhimurium* LT2 has also been cloned and sequenced (Leung and Preiss 1987a). The gene encodes 431 amino acids with a deduced molecular weight of 45,580. The *Salmonella typhimurium* LT2 *glg C* gene and the same gene from *E. coli* K-12 have 90% identity at the amino acid level and 80% identity at the DNA level. Like the *E. coli* ADPglucose pyrophosphorylase, the *Salmonella typhimurium*
30 LT2 ADPglucose pyrophosphorylase is also activated by FBP and is inhibited by AMP (Leung and Preiss 1987b). This substantial conservation in amino acid sequences suggests that introduction

of mutations which cause enhancement of ADPGPP activity in *E. coli* into *S. typhimurium* ADPGPP gene should have a similar effect on the ADPGPP enzyme of this organism.

5 A number of other bacterial ADPglucose pyrophosphorylases have been characterized by their response to activators and inhibitors (for review see: Preiss 1973). Like the *Escherichia coli* ADPglucose pyrophosphorylase, the ADPglucose pyrophosphorylases from *Aerobacter aerogenes*, *Aerobacter cloacae*, *Citrobacter freundii*, and *Escherichia*
10 *aureus* are all activated by FBP and are inhibited by AMP. The ADPglucose pyrophosphorylase from *Aeromonas formicans* is activated by fructose 6-phosphate or FBP, and is inhibited by ADP. The *Serratia marcescens* ADPglucose pyrophosphorylase, however, was not activated by any metabolite tested. The
15 photosynthetic *Rhodospirillum rubrum* has an ADPglucose pyrophosphorylase that is activated by pyruvate, and none of the tested compounds, including P_i , AMP or ADP, inhibit the enzyme. Several algal ADPglucose pyrophosphorylases have
20 been studied and found to have regulation similar to that found for plant ADPglucose pyrophosphorylases. Obviously, the ADPglucose pyrophosphorylases from many organisms could be used to increase starch biosynthesis and accumulation in plants.

25 In addition to *E. coli* and plant ADPGPP enzymes, other sources, including but not limited to cyanobacteria, algae, and other procaryotic and eucaryotic cells can serve as sources for ADPGPP genes. For example, isolation of the *Synechocystis* and the *Anabaena* ADPGPP genes could be performed using
30 oligonucleotides corresponding to the *E. coli* ADPGPP activator site, (amino acid residues 25-42 of Figure 1), which is highly conserved across widely divergent species. Oligonucleotides

corresponding to this region would facilitate gene isolation when used as probes of genomic libraries. Alternatively, the PCR reaction (described in Example 1) could be used to amplify segments of an ADPGPP gene by using 5' primers corresponding to the *E. coli* activator site, and 3' primers corresponding to *E. coli* catalytic sites, for example, the *E. coli* ADPglucose binding site. Products of the PCR reaction could be used as probes of genomic libraries for isolation of the corresponding full length gene.

Plant ADPglucose Pyrophosphorylases

At one time, UDPglucose was thought to be the primary substrate for starch biosynthesis in plants. However, ADPglucose was found to be a better substrate for starch biosynthesis than UDPglucose (Recondo, 1961). This same report states that ADPglucose pyrophosphorylase activity was found in plant material.

A spinach leaf ADPglucose pyrophosphorylase was partially purified and was shown to be activated by 3-phosphoglycerate (3-PGA) and inhibited by inorganic phosphate (Ghosh et al., 1966). The report by Ghosh et al. suggested that the biosynthesis of leaf starch was regulated by the level of ADPglucose. The activator, 3-PGA, is the primary product of CO₂ fixation in photosynthesis. During photosynthesis, the levels of 3-PGA would increase, causing activation of ADPglucose pyrophosphorylase. At the same time, the levels of P_i would decrease because of photophosphorylation, decreasing the inhibition of ADPglucose pyrophosphorylase. These changes would cause an increase in ADPglucose production and starch biosynthesis. During darkness, 3-PGA levels would decrease,

and P_i levels would increase, decreasing the activity of ADPglucose pyrophosphorylase and, therefore, decreasing biosynthesis of ADPG and starch (Ghosh, 1966).

5 The ADPglucose pyrophosphorylase from spinach leaves was later purified to homogeneity and shown to contain subunits of 51 and 54 kDa (Morell, 1987). Based on antibodies raised against the two subunits, the 51 kDa protein has homology with both the maize endosperm and potato tuber
10 ADPglucose pyrophosphorylases, but not with the spinach leaf 54 kDa protein.

 The sequence of a rice endosperm ADPglucose pyrophosphorylase subunit cDNA clone has been reported (Anderson, 1989a). The clone encoded a protein of 483 amino
15 acids. A comparison of the rice endosperm ADPglucose pyrophosphorylase and the *E. coli* ADPglucose pyrophosphorylase protein sequences shows about 30% identity. Also in 1989, an almost full-length cDNA clone for the wheat endosperm ADPglucose pyrophosphorylase was sequenced (Olive, 1989).
20 The wheat endosperm ADPglucose pyrophosphorylase clone has about 24% identity with the *E. coli* ADPglucose pyrophosphorylase protein sequence, while the wheat and the rice clones have 40% identity at the protein level.

 Further evidence for the existence of deregulated wild
25 type plant ADPglucose pyrophosphorylases is found in the paper by Olive et al. (Olive, 1989). They claim that the wheat leaf and endosperm ADPglucose pyrophosphorylases have very different allosteric regulation. The endosperm ADPglucose pyrophosphorylase is not activated by 3-PGA and requires ten
30 times more of the inhibitor, orthophosphate, to achieve 50% inhibition than the leaf enzyme.

5 The maize endosperm ADPglucose pyrophosphorylase has been purified and shown to have catalytic and regulatory properties similar to those of other plant ADPglucose pyrophosphorylases (Plaxton, 1987). The native molecular weight of the maize endosperm enzyme is 230,000, and it is composed of four subunits of similar size.

10 The native molecular weight of the potato tuber ADPglucose pyrophosphorylase is reported to be 200,000, with a subunit size of 50,000 (Sowokinos, 1982). Activity of the tuber ADPglucose pyrophosphorylase is almost completely dependent on 3-PGA, and as with other plant ADPglucose pyrophosphorylases, is inhibited by P_i . The potato tuber and leaf ADPglucose pyrophosphorylases have been demonstrated to be similar in physical, catalytic, and allosteric properties (Anderson, 1989b).

Production of Altered ADPglucose Pyrophosphorylase Genes by Mutagenesis

20 Those skilled in the art will recognize that while not absolutely required, enhanced results are to be obtained by using ADPglucose pyrophosphorylase genes which are subject to reduced allosteric regulation ("deregulated") and more preferably not subject to significant levels of allosteric regulation ("unregulated") while maintaining adequate catalytic activity.

25 The structural coding sequence for a bacterial or plant ADPglucose pyrophosphorylase enzyme can be mutagenized in *E. coli* or another suitable host and screened for increased glycogen production as described for the *glg C16* gene of *E. coli*.

30 It should be realized that use of a gene encoding an ADPglucose pyrophosphorylase enzyme which is only subject to modulators (activators/inhibitors) which are present in the selected plant at

levels which do not significantly inhibit the catalytic activity will not require enzyme (gene) modification. These "unregulated" or "deregulated" ADPglucose pyrophosphorylase genes can then be inserted into plants as described herein to obtain transgenic plants having increased starch content.

For example, any ADPglucose pyrophosphorylase gene can be cloned into the *E. coli* B strain AC70R1-504 (Leung, 1986). This strain has a defective ADPglucose pyrophosphorylase gene, and is derepressed five- to seven-fold for the other glycogen biosynthetic enzymes. The ADPglucose pyrophosphorylase gene/cDNA's can be put on a plasmid behind the *E. coli glg C* promoter or any other bacterial promoter. This construct can then be subjected to either site-directed or random mutagenesis. After mutagenesis, the cells would be plated on rich medium with 1% glucose. After the colonies have developed, the plates would be flooded with iodine solution (0.2w/v% I₂, 0.4w/v% KI in H₂O, Creuzet-Sigal, 1972). By comparison with an identical plate containing non-mutated *E. coli*, colonies that are producing more glycogen can be detected by their darker staining.

Since the mutagenesis procedure could have created promoter mutations, any putative ADPglucose pyrophosphorylase mutant from the first round screening will have to have the ADPglucose pyrophosphorylase gene recloned into non-mutated vector and the resulting plasmid will be screened in the same manner. The mutants that make it though both rounds of screening will then have their ADPglucose pyrophosphorylase activities assayed with and without the activators and inhibitors. By comparing the mutated ADPglucose pyrophosphorylase's responses to activators and inhibitors to the non-mutated enzymes, the new mutant can be characterized.

The report by Plaxton and Preiss in 1987 demonstrates that the maize endosperm ADPglucose pyrophosphorylase has regulatory properties similar to those of the other plant ADPglucose pyrophosphorylases (Plaxton and Preiss 1987).
5 They show that earlier reports claiming that the maize endosperm ADPglucose pyrophosphorylase had enhanced activity in the absence of activator (3-PGA) and decreased sensitivity to the inhibitor (P_i), was due to proteolytic cleavage of the enzyme during the isolation procedure. By altering an
10 ADPglucose pyrophosphorylase gene to produce an enzyme analagous to the proteolytically cleaved maize endosperm ADPglucose pyrophosphorylase, decreased allosteric regulation will be achieved.

15 To assay a liquid culture of *E. coli* for ADPglucose pyrophosphorylase activity, the cells are spun down in a centrifuge and resuspended in about 2 ml of extraction buffer (0.05 M glycylglycine pH 7.0, 5.0 mM DTE, 1.0 mM EDTA) per gram of cell paste. The cells are lysed by passing twice through
20 a French Press. The cell extracts are spun in a microcentrifuge for 5 minutes, and the supernatants are desalted by passing through a G-50 spin column.

The enzyme assay for the synthesis of ADPglucose is a modification of a published procedure (Haugen, 1976). Each 100
25 μ l assay contains: 10 μ mole Hepes pH 7.7, 50 μ g BSA, 0.05 μ mole of [14 C]glucose-1-phosphate, 0.15 μ mole ATP, 0.5 μ mole $MgCl_2$, 0.1 μ g of crystalline yeast inorganic pyrophosphatase, 1 mM ammonium molybdate, enzyme, activators or inhibitors as desired, and water. The assay is incubated at 37°C for 10
30 minutes, and is stopped by boiling for 60 seconds. The assay is spun down in a microcentrifuge, and 40 μ l of the supernatant is injected onto a Synchrom Synchropak AX-100 anion exchange

HPLC column. The sample is eluted with 65 mM KPi pH 5.5. Unreacted [^{14}C]glucose-1-phosphate elutes around 7-8 minutes, and [^{14}C]ADPglucose elutes at approximately 13 minutes. Enzyme activity is determined by the amount of radioactivity found in the ADPglucose peak.

The plant ADPGPP enzyme activity is tightly regulated, by both positive (3-phosphoglycerate; 3-PGA) and negative effectors (inorganic phosphate; P_i) (Ghosh and Preiss, 1966; Copeland and Preiss 1981; Sowokinos and Preiss 1982; Morell et al., 1987; Plaxton and Preiss, 1987; Preiss, 1988;) and the ratio of 3PGA: P_i plays a prominent role in regulating starch biosynthesis by modulating the ADPGPP activity (Santarius and Heber, 1965; Heldt et al., 1977; Kaiser and Bassham, 1979). The plant ADPGPP enzymes are heterotetramers of two large/"shrunk" and two small/"Brittle" subunits (Morell et al., 1987; Lin et al., 1988a, 1988b; Krishnan et al., 1986; Okita et al., 1990) and there is strong evidence to suggest that the heterotetramer is the most active form of ADPGPP. Support for this suggestion comes from the isolation of plant "starchless" mutants that are deficient in either of the subunits (Tsai and Nelson, 1966; Dickinson and Preiss, 1969; Lin et al., 1988a, 1988b) and from the characterization of an "ADPGPP" homotetramer of small subunits that was found to have only low enzyme activity (Lin et al., 1988b). In addition, proposed effector interaction residues have been identified for both subunits (Morell et al., 1988).

Unregulated enzyme variants of the plant ADPGPP are identified and characterized in a manner similar to that which resulted in the isolation of the *E. coli glgC16* and related mutants. A number of plant ADPGPP cDNA's, or portions of such cDNA's, for both the large and small subunits, have been

cloned from both monocots and dicots (Anderson et al., 1989a; Olive et al., 1989; Muller et al., 1990; Bhave et al., 1990; du Jardin and Berhin, 1991) The proteins encoded by the plant cDNA's, as well as those described from bacteria, show a high degree of conservation (Bhave et al., 1990). In particular, a highly conserved region, also containing some of the residues implicated in enzyme function and effector interactions, has been identified (Morell et al., 1988; du Jardin and Berhin, 1991). Clones of the potato tuber ADPGPP subunit genes have been isolated. These include a complete small subunit gene, assembled by addition of sequences from the first exon of the genomic clone with a nearly full-length cDNA clone of the same gene, and an almost complete gene for the large subunit. The nucleotide sequence (SEQ ID NO:7) and the amino acid sequence (SEQ ID NO:8) of the assembled small subunit gene is presented in Figure 5. The nucleotide sequence presented here differs from the gene originally isolated in the following ways: a *Bgl*II+*Nco*I site was introduced at the ATG codon to facilitate the cloning of the gene into *E. coli* and plant expression vectors by site directed mutagenesis utilizing the oligonucleotide primer sequence

GTTGATAACAAGATCTGTTAACCATGGCGGCTTCC (SEQ ID NO:11).

A *Sac*I site was introduced at the stop codon utilizing the oligonucleotide primer sequence

CCAGTTAAAACGGAGCTCATCAGATGATGATTC (SEQ ID NO:12).

The *Sac*I site serves as a 3' cloning site. An internal *Bgl*II site was removed utilizing the oligonucleotide primer sequence

GTGTGAGAACATAAATCTTGGATATGTTAC (SEQ ID NO:13).

This assembled gene was expressed in *E. coli* under the control of the *recA* promoter in a *PrecA-gene10L* expression cassette (Wong et al., 1988) to produce measurable levels of the protein. An initiating methionine codon is placed by site-directed mutagenesis utilizing the oligonucleotide primer sequence GAATTCACAGGGCCATGGCTCTAGACCC (SEQ ID NO:14) to express the mature gene.

The nucleotide sequence (SEQ ID NO:9) and the amino acid sequence (SEQ ID NO:10) of the almost complete large subunit gene is presented in Figure 6. An initiating methionine codon has been placed at the mature N-terminus by site-directed mutagenesis utilizing the oligonucleotide primer sequence AAGATCAAACCTGCCATGGCTTACTCTGTGATCACTACTG (SEQ ID NO:15).

The purpose of the initiating methionine is to facilitate the expression of this large subunit gene in *E. coli*. A *Hind*III site is located 103 bp after the stop codon and serves as the 3' cloning site. The complete large ADPGPP gene is isolated by the 5' RACE procedure (Rapid Amplification of cDNA Ends; Frohman, 1990; Frohman et al., 1988; Loh et al., 1989). The oligonucleotide primers for this procedure are as follows:

1) GGGAATTCAAGCTTGGATCCCGGGCCCCCCCCCCCCCCCCC (SEQ ID NO:16);

2) GGGAATTCAAGCTTGGATCCCGGG (SEQ ID NO:17); and

3) CCTCTAGACAGTCGATCAGGAGCAGATGTACG (SEQ ID NO:18).

The first two are the equivalent to the ANpolyC and the AN primers of Loh et al. (1989), respectively, and the third is the reverse complement to a sequence in the large ADPGPP gene, located after the *Pst* I site in the sequence in Figure 6. The PCR 5' sequence products are cloned as *Eco*RI/*Hind*III/*Bam*HI-*Pst*I

fragments and are easily assembled with the existing gene portion.

5 The weakly regulated enzyme mutants of ADPGPP are identified by initially scoring colonies from a mutagenized *E. coli* culture that show elevated glycogen synthesis, by iodine staining of 24-48 hour colonies on Luria-Agar plates containing glucose at 1%, and then by characterizing the responses of the ADPGPP enzymes from these isolates to the positive and negative effectors of this activity (Cattaneo et al., 1969; Preiss et al., 1971). A
10 similar approach is applied to the isolation of such variants of the plant ADPGPP enzymes. Given an expression system for each of the subunit genes, mutagenesis of each gene is carried out separately, by any of a variety of known means, both chemical or physical (Miller, 1972) on cultures containing the
15 gene or on purified DNA. Another approach is to use a PCR procedure (Ehrlich, 1989) on the complete gene in the presence of inhibiting Mn^{++} ions, a condition that leads to a high rate of misincorporation of nucleotides. A PCR procedure may also be used with primers adjacent to just a specific region of the gene,
20 and this mutagenized fragment then recloned into the non-mutagenized gene segments. A random synthetic oligonucleotide procedure may also be used to generate a highly mutagenized short region of the gene by mixing of nucleotides in the synthesis reaction to result in misincorporation at all
25 positions in this region. This small region is flanked by restriction sites that are used to reinsert this region into the remainder of the gene. The resultant cultures or transformants are screened by the standard iodine method for those exhibiting glycogen levels higher than controls. Preferably this screening
30 is carried out in an *E. coli* strain deficient only in ADPGPP activity (such as *E. coli* LC618' which is a spontaneous mutant of

LC618 (Cattaneo et al., 1969; Creuzet-Sigal et al., 1972) that is phenotypically glycogen-minus and that is complemented to glycogen-plus by *glgC*. The *E. coli* strain should retain those other activities required for glycogen production. Both genes are expressed together in the same *E. coli* host by placing the genes on compatible plasmids with different selectable marker genes, and these plasmids also have similar copy numbers in the bacterial host to maximize heterotetramer formation. Examples of compatible plasmids include the pBR322/pBR327/pUC series (with Ampicillin selection) based on the ColE1 replicon and the pACYC177 plasmid (with Kanamycin selection) based on the p15A replicon (Chang and Cohen, 1978). The use of separate plasmids enables the screening of a mutagenized population of one gene alone, or in conjunction with the second gene following transformation into a competent host expressing the other gene, and the screening of two mutagenized populations following the combining of these in the same host. Following re-isolation of the plasmid DNA from colonies with increased iodine staining, the ADPGPP coding sequences are recloned into expression vectors, the phenotype verified, and the ADPGPP activity and its response to the effector molecules determined. Improved variants will display increased V_{max} , reduced inhibition by the negative effector (P_i), or reduced dependence upon activator (3-PGA) for maximal activity. The assay for such improved characteristics involves the determination of ADPGPP activity in the presence of P_i at 0.045 mM ($I_{0.5} = 0.045$ mM) or in the presence of 3-PGA at 0.075 mM ($A_{0.5} = 0.075$ mM). The useful variants will display <40% inhibition at this concentration of P_i or display >50% activity at this concentration of 3-PGA. Following the isolation of improved variants and the

determination of the subunit or subunits responsible, the mutation(s) are determined by nucleotide sequencing. The mutation is confirmed by recreating this change by site-directed mutagenesis and reassay of ADPGPP activity in the presence of activator and inhibitor. This mutation is then transferred to the equivalent complete ADPGPP cDNA gene, by recloning the region containing the change from the altered bacterial expression form to the plant form containing the amyloplast targeting sequence, or by site-directed mutagenesis of the complete native ADPGPP plant gene.

Chloroplast/Amyloplast Directed Expression of ADPglucose Pyrophos-phorylase Activity

Starch biosynthesis is known to take place in plant chloroplasts and amyloplasts (herein collectively referred to as "plastids". In the plants that have been studied, the ADPglucose pyrophosphorylase is localized to these plastids. ADPglucose pyrophosphorylase is restricted to the chloroplasts in pea shoots (Levi, 1978). In spinach leaves, all of the ADPglucose pyrophosphorylase activity, along with the starch synthase activity, is found in the chloroplasts (Mares, 1978 and Okita, 1979). Immunocytochemical localization shows that the potato tuber ADPglucose pyrophosphorylase is found exclusively in the amyloplasts (Kim, 1989). Studies with rice endosperm also shows that the ADPglucose pyrophosphorylase activity is localized in the amyloplasts (Nakamura, 1989).

Many chloroplast-localized proteins are expressed from nuclear genes as precursors and are targeted to the chloroplast by a chloroplast transit peptide (CTP) that is removed during the import steps. Examples of such chloroplast proteins include the small subunit of Ribulose-1,5-bisphosphate carboxylase

(ssRUBISCO, SSU), 5-enolpyruvateshikimate-3-phosphate synthase (EPSPS), Ferredoxin, Ferredoxin oxidoreductase, the Light-harvesting-complex protein I and protein II, and Thioredoxin F. It has been demonstrated *in vivo* and *in vitro* that non-chloroplast proteins may be targeted to the chloroplast by use of protein fusions with a CTP and that a CTP sequence is sufficient to target a protein to the chloroplast. Likewise, amyloplast-localized proteins are expressed from nuclear genes as precursors and are targeted to the amyloplast by an amyloplast transit peptide (ATP). It is further believed that the chloroplast and amyloplast are developed from common proplastids and are functionally distinct only in that the former is found in photosynthetic cells and the latter in non-photosynthetic cells. In fact, interconversion between the two organella has been observed in plants such as *Picea abies* (Senser, 1975). There are also reports showing that the amyloplast and chloroplast genomes from the same plant are indistinguishable (Scott, 1984; Macherel, 1985 and Catley, 1987). It has been further shown that an amyloplast transit peptide functions to import the associated polypeptide into chloroplasts (Klösgen, 1989).

In the exemplary embodiments, a specialized CTP, derived from the ssRUBISCO 1A gene from *Arabidopsis thaliana* (SSU 1A) (Timko, 1988) was used. This CTP (CTP1) was constructed by a combination of site-directed mutageneses. The CTP1 nucleotide sequence (SEQ ID NO:5) and the corresponding amino acid sequence (SEQ ID NO:6) is also shown in Figure 3. CTP1 is made up of the SSU 1A CTP (amino acid 1-55), the first 23 amino acids of the mature SSU 1A protein (56-78), a serine residue (amino acid 79), a new segment that repeats amino acids 50 to 56 from the CTP and the first two from the mature protein

(amino acids 80-87), and an alanine and methionine residue (amino acid 88 and 89). An *Nco*I restriction site is located at the 3' end (spans the Met codon) to facilitate the construction of precise fusions to the 5' of an ADPglucose pyrophosphorylase gene. At a later stage, a *Bgl*II site was introduced upstream of the N-terminus of the SSU 1A sequences to facilitate the introduction of the fusions into plant transformation vectors. A fusion was assembled between the structural DNA encoding the CTP1 CTP and the *glg C16* gene from *E. coli* to produce a complete structural DNA sequence encoding the plastid transit peptide/ADPglucose pyrophosphorylase fusion polypeptide.

Those skilled in the art will recognize that if either a single plant ADPglucose pyrophosphorylase cDNA encoding shrunken and/or brittle subunits or both plant ADPGPP cDNA's encoding shrunken and brittle subunits is utilized in the practice of the present invention, the endogenous CTP or ATP could most easily and preferably be used. Hence, for purposes of the present invention the term "plastid transit peptides" should be interpreted to include both chloroplast transit peptides and amyloplast transit peptides. Those skilled in the art will also recognize that various other chimeric constructs can be made which utilize the functionality of a particular plastid transit peptide to import the contiguous ADPglucose pyrophosphorylase enzyme into the plant cell chloroplast/amyloplast depending on the promoter tissue specificity. The functionality of the fusion polypeptide can be confirmed using the following *in vitro* assay.

Plastid Uptake Assay

Intact chloroplasts are isolated from lettuce (*Lactuca sativa*, var. *longifolia*) by centrifugation in Percoll/ficoll gradients as modified from Bartlett et al (1982). The final pellet

of intact chloroplasts is suspended in 0.5 ml of sterile 330 mM sorbitol in 50 mM Hepes-KOH, pH 7.7, assayed for chlorophyll (Arnon, 1949), and adjusted to the final chlorophyll concentration of 4 mg/ml (using sorbitol/Hepes). The yield of
5 intact chloroplasts from a single head of lettuce is 3-6mg chlorophyll.

A typical 300 μ l uptake experiment contained 5 mM ATP, 8.3 mM unlabeled methionine, 322 mM sorbitol, 58.3 mM Hepes-KOH (pH 8.0), 50 μ l reticulocyte lysate translation
10 products, and intact chloroplasts from *L. sativa* (200 μ g chlorophyll). The uptake mixture is gently rocked at room temperature (in 10 x 75 mm glass tubes) directly in front of a fiber optic illuminator set at maximum light intensity (150 Watt bulb). Aliquots of the uptake mix (50 μ l) are removed at various
15 times and fractionated over 100 μ l silicone-oil gradients (in 150 μ l polyethylene tubes) by centrifugation at 11,000 X g for 30 seconds. Under these conditions, the intact chloroplasts form a pellet under the silicone-oil layer and the incubation medium (containing the reticulocyte lysate) floats on the surface. After
20 centrifugation, the silicone-oil gradients are immediately frozen in dry ice. The chloroplast pellet is then resuspended in 50-100 μ l of lysis buffer (10 mM Hepes-KOH pH 7.5, 1 mM PMSF, 1 mM benzamidine, 5 mM ϵ -amino-n-caproic acid, and 30 μ g/ml aprotinin) and centrifuged at 15,000 X g for 20 minutes to pellet
25 the thylakoid membranes. The clear supernatant (stromal proteins) from this spin, and an aliquot of the reticulocyte lysate incubation medium from each uptake experiment, are mixed with an equal volume of 2X NaDodSO₄-PAGE sample buffer for
30 electrophoresis (see below).

SDS-PAGE is carried out according to Laemmli (1970) in 3-17% (w/v) acrylamide slab gels (60 mm X 1.5 mm) with 3%

5 (w/v) acrylamide stacking gels (5 mm X 1.5 mm). The gel is fixed for 20-30 minutes in a solution with 40% methanol and 10% acetic acid. Then, the gel is soaked in EN³HANCETM (DuPont) for 20-30 minutes, followed by drying the gel on a gel dryer. The gel is imaged by autoradiography, using an intensifying screen and an overnight exposure to determine whether the ADPglucose pyrophosphorylase is imported into the isolated chloroplasts.

10 An alternative means for enhancing ADPglucose levels in plant cells will be to isolate genes encoding transcription factors which interact with the upstream regulatory elements of the plant ADPglucose pyrophosphorylase gene(s). Enhanced expression of these transcription factors in plant cells can cause
15 enhanced expression of the ADPglucose pyrophosphorylase gene. Under these conditions, the increased starch content is still realized by an increase in the activity of the ADPglucose pyrophosphorylase enzyme although the mechanism is different. Methods for the isolation of transcription factors have
20 been described (Katagiri, 1989).

Polyadenylation Signal

25 The 3' non-translated region of the chimeric plant gene contains a polyadenylation signal which functions in plants to cause the addition of polyadenylate nucleotides to the 3' end of the RNA. Examples of suitable 3' regions are (1) the 3' transcribed, non-translated regions containing the polyadenylated signal of *Agrobacterium* the tumor-inducing (Ti) plasmid genes, such as the nopaline synthase (NOS) gene, and
30 (2) plant genes like the soybean storage protein genes and the small subunit of the ribulose-1,5-bisphosphate carboxylase (ssRUBISCO) gene. An example of a preferred 3' region is that

from the NOS gene, described in greater detail in the examples below.

Plant Transformation/Regeneration

5 Plants which can be made to have increased starch content by practice of the present invention include, but are not limited to, corn, wheat, rice, carrot, onion, pea, tomato, potato, sweet potato, peanut, canola/oilseed rape, barley, sorghum, cassava, banana, soybean, lettuce, apple and walnut.

10 A double-stranded DNA molecule of the present invention containing the functional plant ADPglucose pyrophosphorylase gene can be inserted into the genome of a plant by any suitable method. Suitable plant transformation vectors include those derived from a Ti plasmid of
15 *Agrobacterium tumefaciens*, as well as those disclosed, e.g., by Herrera-Estrella (1983), Bevan (1983), Klee (1985) and EPO publication 120,516 (Schilperoort et al.). In addition to plant transformation vectors derived from the Ti or root-inducing (Ri) plasmids of *Agrobacterium*, alternative methods can be used to
20 insert the DNA constructs of this invention into plant cells. Such methods may involve, for example, the use of liposomes, electroporation, chemicals that increase free DNA uptake, free DNA delivery via microprojectile bombardment, and transformation using viruses or pollen.

25 A plasmid expression vector, suitable for the expression of the *E. coli glgC16* and other ADPGPP genes in monocots is composed of the following: a promoter that is specific or enhanced for expression in the starch storage tissues in monocots, generally the endosperm, such as promoters for the
30 zein genes found in the maize endosperm (Pedersen et al., 1982); an intron that provides a-splice site to facilitate expression of the

gene, such as the ADH1 intron (Callas et al., 1987); and a 3' polyadenylation sequence such as the nopaline synthase 3' sequence (NOS 3'; Fraley et al., 1983). This expression cassette may be assembled on high copy replicons suitable for the production of large quantities of DNA.

A particularly useful *Agrobacterium*-based plant transformation vector for use in transformation of dicotyledonous plants is plasmid vector pMON530 (Rogers, S.G., 1987). Plasmid pMON530 (see Figure 3) is a derivative of pMON505 prepared by transferring the 2.3 kb *Stu*I-*Hind*III fragment of pMON316 (Rogers, S.G., 1987) into pMON526. Plasmid pMON526 is a simple derivative of pMON505 in which the *Sma*I site is removed by digestion with *Xma*I, treatment with Klenow polymerase and ligation. Plasmid pMON530 retains all the properties of pMON505 and the CaMV35S-NOS expression cassette and now contains a unique cleavage site for *Sma*I between the promoter and polyadenylation signal.

Binary vector pMON505 is a derivative of pMON200 (Rogers, S.G., 1987) in which the Ti plasmid homology region, L1H, has been replaced with a 3.8 kb *Hind*III to *Sma*I segment of the mini RK2 plasmid, pTJS75 (Schmidhauser & Helinski, 1985). This segment contains the RK2 origin of replication, *ori*V, and the origin of transfer, *ori*T, for conjugation into *Agrobacterium* using the tri-parental mating procedure (Horsch & Klee, 1986). Plasmid pMON505 retains all the important features of pMON200 including the synthetic multi-linker for insertion of desired DNA fragments, the chimeric NOS/NPTII/NOS gene for kanamycin resistance in plant cells, the spectinomycin/streptomycin resistance determinant for selection in *E. coli* and *A. tumefaciens*, an intact nopaline synthase gene for facile scoring of transformants and inheritance in progeny and

5 a pBR322 origin of replication for ease in making large amounts of the vector in *E. coli*. Plasmid pMON505 contains a single T-DNA border derived from the right end of the pTiT37 nopaline-type T-DNA. Southern analyses have shown that plasmid pMON505 and any DNA that it carries are integrated into the plant genome, that is, the entire plasmid is the T-DNA that is inserted into the plant genome. One end of the integrated DNA is located between the right border sequence and the nopaline synthase gene and the other end is between the border sequence and the pBR322 sequences.

10 When adequate numbers of cells (or protoplasts) containing the ADPglucose pyrophosphorylase gene or cDNA are obtained, the cells (or protoplasts) are regenerated into whole plants. Choice of methodology for the regeneration step is not critical, with suitable protocols being available for hosts from Leguminosae (alfalfa, soybean, clover, etc.), Umbelliferae (carrot, celery, parsnip), Cruciferae (cabbage, radish, rapeseed, etc.), Cucurbitaceae (melons and cucumber), Gramineae (wheat, rice, corn, etc.), Solanaceae (potato, tobacco, tomato, peppers) and various floral crops. See, e.g., Ammirato (1984); Shimamoto, 1989; Fromm, 1990; Vasil, 1990.

25 The following examples are provided to better elucidate the practice of the present invention and should not be interpreted in any way to limit the scope of the present invention. Those skilled in the art will recognize that various modifications, truncations, etc. can be made to the methods and genes described herein while not departing from the spirit and scope of the present invention.

EXAMPLES

Example 1

5 To express the *E. coli glg C16* gene in plant cells, and to target the enzyme to the plastids, the gene needed to be fused to a DNA encoding the plastid-targeting transit peptide (hereinafter referred to as the CTP/ADPglucose pyrophosphorylase gene), and to the proper plant regulatory regions. This was accomplished by cloning the *glg C16* gene into a series of plasmid vectors that contained the needed sequences.

10 The plasmid pLP226 contains the *glg C16* gene on a HincII fragment, cloned into a pUC8 vector at the HincII site (Leung et al. 1986). pLP226 was obtained from Dr. Jack Preiss at Michigan State University, and was transformed into frozen competent *E. coli* JM101 cells, prepared by the calcium chloride method (Sambrook et al., 1989). The transformed cells were
15 plated on 2XYT (infra) plates that contained ampicillin at 100 µg/ml. The plasmid pLP226 was purified by the rapid alkaline extraction procedure (RAE) from a 5 ml overnight culture (Birnboim and Doly 1979).

20 To fuse the *glg C16* gene to the DNA encoding the chloroplast transit peptide, a NcoI site was needed at the 5' end of the gene. A SacI site downstream of the termination codon was also needed to move the CTP/ADPglucose pyrophosphorylase gene into the next vector. In order to
25 introduce these sites, a PCR reaction (#13) was run using approximately 20 ng of rapid alkaline extraction-purified plasmid pLP226 for a template. The reaction was set up following the recommendations of the manufacturer (Perkin Elmer Cetus). The primers were QSP3 and QSP7. QSP3 was
30 designed to introduce the NcoI site that would include the start codon for the *glg C 16* gene. The QSP7 primer hybridized in the

5 3' nontranslated region of the *glg* C16 gene and added a SacI site. The Thermal Cycler was programmed for 30 cycles with a 1 minute 94°C denaturation step, a 2 minute 50°C annealing step, and a 3 minute 72°C extension step. After each cycle, the extension step was increased by 15 seconds.

QSP3 Primer:

5'-GGAGTTAGCCATGGTTAGTTTAGAG-3' (SEQ ID NO:19)

10

QSP7 Primer:

5'-GGCCGAGCTCGTCAACGCCGTCTGCGATTGTGC-3'
(SEQ ID NO:20)

15

The vector that the PCR product was cloned into was pGEM3zf+ (obtained from Promega, Madison, WI) that had been digested with SacI and Hind III, and had the DNA for the modified *Arabidopsis* small subunit CTP1 ligated at the HindIII site. The DNA (SEQ ID NO:5) and amino acid sequence (SEQ ID NO:6) of this CTP1 are shown in Figure 3.

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The linearized vector was treated with 5 units of calf intestinal alkaline phosphatase for 30 minutes at 56°C. Then, both the vector and the PCR #13 fragment, which had the *glg* C16 gene with the new NcoI and SacI sites, were run on an agarose gel and the fragments were purified by binding to DEAE membranes. The protocol used for the fragment purification with the DEAE membrane is from Schleicher and Schuell, and is titled "Binding and Recovery of DNA and RNA Using S and S DEAE Membrane."

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Ligation #5 fused the *glg* C16 gene to the DNA for the modified *Arabidopsis* SSU CTP with the pGEM3zf+. The ligation contained 3 µl of vector that had been digested with NcoI and

5 SacI, along with 3 μ l of the PCR #13 product, that had also been cut with NcoI and SacI and repurified on a gel. 5 μ l (of 20 μ l total) of ligation #5 was transformed into frozen competent JM101 cells, and the transformed cells were plated on 2XYT plates (16 g/l Bacto-tryptone, 10 g/l yeast extract, 10 g/l NaCl, pH 7.3, and solidified with 1.5% agar) containing ampicillin.

10 Sample 1 was picked from a plate after overnight growth. This sample was inoculated into 4 ml of 2XYT media and grown overnight at 37°C. The plasmid was isolated by the rapid alkaline extraction procedure, and the DNA was digested with EcoRI, NcoI, and EcoRI and NcoI together. The digest was separated on an agarose gel, and the expected fragments were observed. The plasmid isolated from sample 1 was designated pMON20100, and consisted of pGEM3zf+, the DNA for the modified *Arabidopsis* SSU CTP, and the *glg C16* gene. The fusion was in the orientation that allowed it to be transcribed from the SP6 polymerase promoter.

20 To test this construct for import of the ADPglucose pyrophosphorylase into isolated lettuce chloroplasts, the CTP/ADPglucose pyrophosphorylase fusion needed to be transcribed and translated to produce [³⁵S]-labeled ADPglucose pyrophosphorylase. To make a DNA template for transcription by the SP6 polymerase, the CTP/ADPglucose pyrophosphorylase region of pMON20100 was amplified by PCR to generate a large amount of linear DNA. To do this, about 0.1 μ l of pMON20100, that had been purified by rapid alkaline extraction, was used as a template in PCR reaction #80. The primers were a commercially available SP6 promoter primer (Promega) and the oligo QSP7. The SP6 primer hybridized to the SP6 promoter in the vector, and included the entire SP6 promoter sequence. Therefore, a PCR product primed with this oligonucleotide will

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contain the recognition sequence for the SP6 polymerase. The QSP7 primer will hybridize in the 3' nontranslated region of the *glg C16* gene. This is the same primer that was used to introduce a SacI site downstream of the *glg C16* termination codon. The Thermal Cycler was programmed for 30 cycles with a 1 minute denaturation at 94°C, a 2 minute annealing at 55°C, and a 3 minute extension at 72°C. After each cycle, 15 seconds were added to the extension step.

SP6 Promoter Primer:

5'-GATTTAGGTGACACTATAG-3' (SEQ ID NO:21)

5 µl of PCR reaction #80 was run on an agarose gel and purified by binding to DEAE membrane. The DNA was eluted and dissolved in 20 µl of TE. 2µl of the gel-purified PCR #80 product was used in an SP6 RNA polymerase in vitro transcription reaction. The reaction conditions were those described by the supplier (Promega) for the synthesis of large amounts of RNA (100 µl reaction). The RNA produced from the PCR reaction #80 DNA was used for *in vitro* translation with the rabbit reticulocyte lysate system (Promega). ³⁵S-labeled protein made from pMON20100 (ie:PCR reaction# 80) was used for an in vitro chloroplast import assay as previously described. After processing the samples from the chloroplast import assay, the samples were subjected to electrophoresis on SDS-PAGE gels with a 3-17% polyacrylamide gradient. The gel was fixed for 20-30 minutes in a solution with 40% methanol and 10% acetic acid. Then, the gel was soaked in EN³HANCE™ for 20-30 minutes, followed by drying the gel on a gel dryer. The gel was imaged by autoradiography, using an intensifying screen and

an overnight exposure. The results demonstrated that the fusion protein was imported into the isolated chloroplasts.

The construct in pMON20100 was next engineered to be fused to the En-CaMV35S promoter (Kay, R. 1987) and the NOS 3' end (Bevan, M. 1983) isolated from pMON999. PCR reaction 114 contained plasmid pMON 20100 as a template, and used primers QSM11 and QSM10. QSM11 annealed to the DNA for the modified *Arabidopsis* SSU CTP and created a BglII site 7 bp upstream from the ATG start codon. QSM10 annealed to the 3' end of the *glg C16* gene and added an XbaI site immediately after the termination codon, and added a SacI site 5 bp after the termination codon. The SacI site that had earlier been added to the *glg C16* gene was approximately 100 bp downstream of the termination codon. The Thermal Cycler was programmed for 25 cycles with a 1 minute 94°C denaturation, a 2 minute 55°C annealing, and a 3 minute 72°C extension step. With each cycle, 15 seconds was added to the extension step.

QSM11 Primer:

5'-AGAGAGATCTAGAACAATGGCTTCCTCTATGCTCTCTTCCGC-3'
(SEQ ID NO:22)

QSM10 Primer:

5'-GGCCGAGCTCTAGATTATCGCTCCTGTTTATGCCCTAAC-3' (SEQ ID NO:23)

Ninety-five (95)µl (from 100 µl total volume) of PCR reaction #114 was ethanol precipitated, and resuspended in 20 µl of TE. Five (5) µl of this was digested with BglII (4 units) and SacI (10 units) overnight at 37°C. Five (5) µl (5 µg) of the vector, pMON999, which contains the En-CaMV35S promoter and the

NOS 3' end, was digested in the same manner. After digestion with the restriction enzymes, the DNAs were run on an agarose gel and purified by binding to DEAE membranes. Each of the DNAs were dissolved in 20 μ l of TE. One (1) μ l of PCR 114 was ligated with 3 μ l of the vector, in a total volume of 20 μ l. The ligation mixture was incubated at 14°C for 7 hours. Ten (10) μ l of the ligation was transformed into frozen competent MM294 cells and plated on LB plates (10 g/l Bacto-tryptone, 5 g/l yeast extract, 10 g/l NaCl, and 1.5% agar to solidify) with 100 μ g/ml ampicillin. Colonies were picked and inoculated into tubes with 5 ml of LB media with 100 μ g/ml ampicillin, for overnight growth. The 5 ml overnight cultures were used for rapid alkaline extractions to isolate the plasmid DNAs. The DNAs were digested with EcoRI, and separate aliquots were digested with NotI. After analyzing these samples on agarose gels, the plasmid pMON20102 was confirmed to have the 497 bp EcoRI fragment that is characteristic of the *glg C16* gene. This plasmid also contained the 2.5 kb NotI fragment which contained the En-CaMV35S promoter, the DNA for the modified *Arabidopsis* SSU CTP, the *glg C16* gene, and the NOS 3' end.

The 2.5 kb NotI cassette was then transferred into a plant transformation vector, pMON530 (Figure 4). pMON530 contains a unique NotI site in the RK2 region, exactly 600 bp after the HindIII site. A description of the construction of pMON530 can be found in Rogers et al., 1987. Twenty (20) μ g of pMON530 was digested with 40 units of NotI overnight at 37°C. The digested vector was then dephosphorylated with 22 units of calf alkaline intestinal phosphatase at 37°C for about 1 hour. The pMON530 vector was extracted with phenol/chloroform, then chloroform, and was ethanol precipitated. Ten (10) μ g of plasmid pMON20102 was also digested overnight at 37°C with 40

units of NotI. The NotI-digested pMON530 vector was ligated to the NotI cassette from plasmid pMON20102 at 15°C overnight. The ligation was transformed into frozen competent JM101 *E. coli* cells, and the transformed cells were plated on LB with 75 µg/ml spectinomycin.

Nine colonies were picked from the transformation plate and grown in 5 ml LB cultures for screening. Plasmids from 5 ml cultures were prepared by the rapid alkaline extraction procedure. The DNAs were first screened by Sall digestions which were separated on a 1% agarose gel. By comparing the resulting pattern with the Sall digest of the parent plasmid, pMON530, the correct construct was isolated. The construct was designated pMON20104 and the orientation determined by PstI digestion and NcoI/BglII double digestion. The En-CaMV35S promoter driving the CTP/ADPglucose pyrophosphorylase gene is in the same orientation as the CaMV35S promoter that was already present in pMON530.

In preparation for transforming tobacco cells, pMON20104 was mated into *Agrobacterium* ASE by a triparental mating with the helper plasmid pRK2013. The *Agrobacterium* was grown 1.5 days in LB with 25 µg/ml chloramphenicol and 50 µg/ml kanamycin at 30°C. *E. coli* containing pRK2013 was grown overnight in kanamycin (50 µg/ml). This culture was started with several colonies from a plate. *E. coli* with pMON20104 was grown in LB with 75 µg/ml spectinomycin. After all of the cultures were grown, 4 ml of LB was added to a tube with 100 µl each of *Agrobacterium* ASE, pRK2013, and pMON20104. This mixture was spun in a microfuge for 5 minutes and decanted. The pellet was resuspended in the remaining liquid, and pipetted into the middle of an LB plate. After overnight growth at 30°C, a loop of cells from this plate was

streaked onto an LB plate with 75 µg/ml spectinomycin and 25 µg/ml chloramphenicol.

5 After 1-2 days at 30°C, the plate from the triparental mating of pMON20104, *Agrobacterium* ASE, and pRK2013, had growing colonies, while the control plate from the mating of pMON20104 and ASE (without pRK2013, which is needed for mobilization) did not. After the triparental mating, 2 colonies were picked from the plate, inoculated into a liquid culture with 10 75 µg/ml spectinomycin, 25 µg/ml chloramphenicol, and 50 µg/ml kanamycin, and grown at 30°C. These two cultures were used for transformation into tobacco.

15 The tobacco leaf disc transformation protocol uses healthy leaf tissue about 1 month old. After a 15-20 minute surface sterilization with 10% Clorox plus a surfactant, the leaves were rinsed 3 times in sterile water. Using a sterile paper punch, leaf discs are punched and placed upside down on MS104 media (MS salts 4.3 g/l, sucrose 30 g/l, B5 vitamins 500X 2 ml/l, NAA 0.1 mg/l, and BA 1.0 mg/l) for a 1 day preculture.

20 The discs were then inoculated with an overnight culture of *Agrobacterium* ASE:pMON20104 that had been diluted 1/5 (ie: about 0.6 OD). The inoculation was done by placing the discs in centrifuge tubes with the culture. After 30 to 60 seconds, the liquid was drained off and the discs were blotted between sterile filter paper. The discs were then placed upside down on MS104 25 feeder plates with a filter disc to co-culture.

30 After 2-3 days of co-culture, the discs were transferred, still upside down, to selection plates with MS104 media. After 2-3 weeks, callus formed, and individual clumps were separated from the leaf discs. Shoots were cleanly cut from the callus when they were large enough to distinguish from stems. The shoots were placed on hormone-free rooting media (MSO: MS

5 salts 4.3 g/l, sucrose 30 g/l, and B5 vitamins 500X 2 ml/l) with selection. Roots formed in 1-2 weeks. Rooted shoots were placed in soil and were kept in a high humidity environment (ie: plastic containers or bags). The shoots were hardened off by gradually exposing them to ambient humidity conditions.

10 Starch levels of transformed callus tissue was quantitated by a modification of the procedure of Lin et al. (Lin et al. 1988a). Clumps of callus were removed from their plates, taking care not to include any agar. The callus was put into 1.5 ml microcentrifuge tubes and dried under a vacuum in a SPEED VAC™ (Savant). After several hours of drying, the tubes were removed and weighed on an analytical balance to the closest 0.1 mg. The tubes were returned to the SPEED VAC™ for several
15 more hours, then were reweighed to determine if a stable dry weight had been obtained. The dried callus was ground in the tube and thoroughly mixed, to give a homogenous sample. An aliquot of each dried callus sample was removed and put into a preweighed 1.5 ml microcentrifuge tube. These new tubes were then reweighed, and the weight of the calli samples in them was
20 determined. The samples ranged from 9 to 34 mg.

Approximately 1 ml of 80% ethanol was added to each tube, and the tubes were incubated in a 70°C water bath for 10-20 minutes. The samples were then spun down, and the ethanol was removed. The ethanol wash was done 2 more times. After
25 the last ethanol wash, the samples were dried in a Speed Vac™, then 200 µl of 0.2 N KOH was added to each tube. The samples were ground using an overhead stirrer, then the samples were heated at 100°C for 30 minutes. Before heating the tubes, several
30 small holes were made in the caps with a needle. This prevented the caps from popping off and causing a loss of sample. After the heating step, 40 µl of 1N acetic acid was added

to each sample. 35 μ l (7.4 units) of pancreatic alpha-amylase was added, followed by a 30 minute incubation at 37°C. Next, 5 units (in 5 μ l) amyloglucosidase (from *Aspergillus niger*) was added to each sample, along with 160 μ l of 100 mM sodium acetate pH. 4.6. The samples were heated to 55°C for 1 hour, boiled for 2-3 minutes, and briefly spun down in a microcentrifuge. At this point, the samples were again dried in a Speed Vac™, and were resuspended in 1000 μ l of 100 mM Tris-Cl pH 7.5.

The samples were then assayed for glucose using the Glucose [HK] assay from Sigma (catalogue # 16-10). Using this assay, glucose in the samples (+ATP) is converted to glucose-6-phosphate + ADP by hexokinase. The glucose-6-phosphate (+NAD) is converted to 6-phosphogluconate + NADH. The increase in absorbance at 340 nm, due to NADH, is measured and is directly proportional to the glucose concentration. All assays and calculations were done as recommended by Sigma. The assays were conducted following Sigma's "Alternate Procedure," at room temperature with 10 μ l of sample per assay, or 5 μ l of sample + 5 μ l of 100mM Tris-Cl pH 7.5. The percent starch was determined by dividing the amount (weight) of glucose by the dry weight of the callus.

For the Western blots, a portion of the dried, homogenized callus from each of the 12 samples, plus the 2 control samples, was resuspended in 200 μ l of extraction buffer (100 mM Tris-Cl pH 7.1, 1 mM EDTA, 10% glycerol, 5 mM DTT, 1 mM benzamidine). Each sample was ground with an overhead stirrer, spun in a microcentrifuge for 5 minutes at full speed, and the supernatants were removed to new tubes. The protein concentration in each sample was determined by the BioRad protein assay (Lowry et al. 1951), with BSA as a standard.

5 Twenty-five (25) μ g of each sample was loaded onto SDS polyacrylamide gels, with a 7-17% polyacrylamide gradient. Since the samples were loaded onto two gels, the same control callus sample was loaded onto each gel. In addition, a control
spiked with 10 ng of pure *E. coli* ADPglucose pyrophosphorylase was loaded onto each gel.

10 After electrophoresis, the gels were blotted to nitrocellulose using a PolyBlot™ apparatus from American Bionetics. The Western blots were processed according to the protocol provided by Promega. The filters were blocked with 1% BSA in TBST (10 mM Tris-Cl pH 8.0, 150 mM NaCl, and 0.05% Tween 20), for 30 minutes. Ten (10.0) ml of TBST plus 1.3 μ l of the primary rabbit anti-*E. coli* ADPglucose pyrophosphorylase
15 antibody were mixed, and the filters was incubated with this primary antibody for 30 minutes. The filters were then washed 3 times with about 50 ml of TBST per wash, for 3 washes of 5 minutes each. Ten (10.0) ml of TBST plus 1.3 μ l of the secondary antibody (goat-anti-rabbit conjugated to alkaline phosphatase, Promega) was incubated with the filters for 30 minutes followed
20 again by 3 TBST washes. The signals were visualized using the reaction of alkaline phosphatase with BCIP and NBT, and they were quantitated with a laser densitometer.

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Results:

	<u>Callus Sample</u>	<u>% Starch</u>	<u>Peak Area</u>
5	1	26.9%	0.573
	2	4.6	0.170
	3	6.4	0.0
	4	12.3	0.344
	5	15.3	0.376
	6	11.1	0.314
10	Control 2 + 10 ng	*	0.369
15	7	5.5	ND
	8	5.6	0.117
	9	9.7	0.095
	10	6.6	0.0
	11	11.4	0.376
	12	13.3	0.342
	Control 2 + 10 ng	*	0.329
20	Control 1	3.0	
	Control 2	3.7	

* The spiked samples were only used on the Western blots.

ND = not determined

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The above results show the results of the quantitative starch assays and the integrated peak areas from the Western blots. The % Starch is reported as the percent of starch relative to the dry weight of the callus. The peak area is the integrated area under the peak from a densitometer scan of the corresponding sample on a Western blot. Samples 1-6 were run on one gel, and samples 7-12 were run on another gel. Control 2

was run on both blots with and without 10 ng of purified *E. coli* ADPglucose pyrophosphorylase. The unspiked samples on both gels showed no interfering bands. The spiked samples had the peak areas shown. These results demonstrate that increased APDglucose leads to increased starch content in plant cells.

Example 2

pMON20104, as described in Example 1, has also been transformed into the Desiree potato strain using the published tuber disc transformation protocol of Sheerman and Bevan (Sheerman and Bevan 1988). Virus-free tubers of *Solanum tuberosum* var. Desiree, were peeled, washed briefly in distilled water, and surface sterilized for 15 minutes in 10% sodium hypochlorite which contained a few drops of Tween 20. The tubers were washed 6 times in sterile water, then were immersed in liquid MS medium. A sterile 1 cm diameter cork borer was used to remove sections of the tubers, and these sections were then cut with a scalpel into 1-2 mm discs. The discs were floated in 20 ml of MS medium containing *Agrobacterium* ASE:pMON20104. A 10 ml culture of *Agrobacterium* ASE:pMON20104 was spun down and resuspended in 20 ml of MS medium before use. The culture and the discs were gently shaken in a petri dish. After 20 minutes, the discs were transferred to tobacco feeder plates with 3C5ZR medium (MS salts, 1 mg/l Thiamine HCl, 0.5 mg/l nicotinic acid, 0.5 mg/l pyridoxine HCL, 3% sucrose, 5 μ M zeatin riboside, and 3 μ M IAA aspartic acid, pH 5.9).

After 48 hours, infected discs were put on the new plates with the same medium, but without the feeder layer, and with 500 μ g/ml carbenicillin and 100 μ g/ml kanamycin. The plates were sealed with parafilm and incubated at 25°C with 16

hours of light/day. The discs were subcultured onto fresh plates every 3 weeks, and the carbenicillin concentration was lowered from 500 to 200 $\mu\text{g/ml}$ after 4 weeks in culture. Developing shoots were removed and placed in large test tubes containing MS salts and R3 vitamins (1 mg/l Thiamine HCl, 0.5 mg/l nicotinic acid, 0.5 mg/l pyridoxine HCl) plus 200 $\mu\text{g/ml}$ carbenicillin and 100 $\mu\text{g/ml}$ kanamycin. After roots have formed, the plants are transferred to soil and are gradually hardened off.

These preliminary experiments demonstrate that recovering transgenic plants expressing the ADPGPP gene under the control of the En-CaMV35S promoter is problematic. One potato plant was produced on a sucrose containing medium, but when removed from the medium and placed in soil, it did not survive. This result is not unexpected. The En-CaMV35S promoter is a constitutive promoter and causes expression of the ADPGPP in all tissues of the plant. The constitutive expression of the ADPGPP gene most likely causes a deprivation of the sucrose supply to the growing parts of the plant due to the ADPGPP mediated conversion of sucrose to starch in the sugar exporting cells and tissues of the plant. Thus, this example illustrates the expression of ADPGPP in plant cells and the preference, in most cases, that the ADPGPP be expressed specifically in the target tissue, such as the tuber of a potato or the fruit of a tomato. One of ordinary skill in the art would be able to select from a pool of plants transformed with the En-CaMV35S promoter, a plant expressing ADPGPP within the desired range.

Example 3

Potato tissue has also been transformed to express a CTP/ADPglucose pyrophosphorylase fusion polypeptide driven

by a patatin promoter. This construct causes specific expression of the ADPGPP in potato tubers and increases the level of starch in the tubers.

5 The vector used in the potato transformation is a derivative of the *Agrobacterium* mediated plant transformation vector pMON886. The pMON886 plasmid is made up of the following well characterized segments of DNA. A 0.93 kb fragment isolated from transposon Tn7 which encodes bacterial spectinomycin/streptomycin (Spc/Str) resistance and is a
10 determinant for selection in *E. coli* and *Agrobacterium tumefaciens* (Fling et al., 1985). This is joined to a chimeric kanamycin resistance gene engineered for plant expression to allow selection of the transformed tissue. The chimeric gene
15 consists of the 0.35 kb cauliflower mosaic virus 35S promoter (P-35S) (Odell et al., 1985), the 0.83 kb neomycin phosphotransferase typeII gene (NPTII), and the 0.26 kb 3'-non-translated region of the nopaline synthase gene (NOS 3') (Fraley et al., 1983). The next segment is a 0.75 kb origin of replication from the RK2
20 plasmid (ori-V) (Stalker et al., 1981). It is joined to a 3.1 kb *SalI* to *PvuI* segment of pBR322 which provides the origin of replication for maintenance in *E. coli* (ori-322) and the *bom* site for the conjugational transfer into the *Agrobacterium tumefaciens* cells. Next is a 0.36 kb *PvuI* fragment from the
25 pTiT37 plasmid which contains the nopaline-type T-DNA right border region (Fraley et al., 1985).

 The *glgC16* gene was engineered for expression primarily in the tuber by placing the gene under the control of a tuber-specific promoter. The GlgC16 protein was directed to the
30 plastids within the plant cell due to its synthesis as a C-terminal fusion with a N-terminal protein portion encoding a chloroplast targeting sequence (CTP) derived from that from the SSU 1A

gene from *Arabidopsis thaliana* (Timko et al., 1989). The CTP portion is removed during the import process to liberate the GlgC16 enzyme. Other plant expression signals also include the 3' polyadenylation sequences which are provided by the NOS 3' sequences located downstream from the coding portion of the expression cassette. This cassette was assembled as follows: The patatin promoter was excised from the pBI241.3 plasmid as a *Hind*III-*Bam*HI fragment (The pBI241.3 plasmid contains the patatin-1 promoter segment comprising from the *Acc*I site at 1323 to the *Dra*I site at 2289 [positions refer to the sequence in Bevan et al., 1986] with a *Hind*III linker added at the former and a *Bam*HI linker added at the latter position; Bevan et al., 1986) and ligated together with the CTP1-*glgC16* fusion (the *Bgl*II-*Sac*I fragment from pMON20102 - see Example 1) and pUC-type plasmid vector cut with *Hind*III and *Sac*I (these cloning sites in the vector are flanked by *Not*I recognition sites). The cassette was then introduced, as a *Not*I site in pMON886, such that the expression of the *glgC16* gene is in the same orientation as that of the NPTII (kanamycin) gene. This derivative is pMON20113 which is illustrated in Figure 7.

The pMON20113 vector was mobilized into disarmed *Agrobacterium tumefaciens* strain by the triparental conjugation system using the helper plasmid pRK2013 (Ditta et al., 1980). The disarmed strain ABI was used, carrying a Ti plasmid which was disarmed by removing the phytohormone genes responsible for crown gall disease. The ABI strain is the A208 *Agrobacterium tumefaciens* carrying the disarmed pTiC58 plasmid pMP90RK (Koncz and Schell, 1986). The disarmed Ti plasmid provides the *trfA* gene functions required for autonomous replication of the pMON vector after the conjugation into the ABI strain. When the plant tissue is

incubated with the ABI::pMON conjugate, the vector is transferred to the plant cells by the vir functions encoded by the disarmed pMP90RK Ti plasmid.

5 The pMON20113 construct is then transformed into the
Russet Burbank potato variety. To transform Russet Burbank
potatoes, sterile shoot cultures of Russet Burbank are
maintained in sundae cups containing 8 ml of PM medium
supplemented with 25 mg/L ascorbic acid (Murashige and Skoog
10 (MS) inorganic salts, 30 g/l sucrose, 0.17 g/l $\text{NaH}_2\text{PO}_4\text{H}_2\text{O}$, 0.4
mg/l thiamine-HCl, and 100 mg/l myo-inositol, solidified with 2
g/l Gelrite at pH 6.0). When shoots reach approximately 5 cm in
length, stem internode segments of 3-5 mm are excised and
inoculated with a 1:10 dilution of an overnight culture of
15 *Agrobacterium tumefaciens* from a 4 day old plate culture. The
stem explants are co-cultured for 2 days at 20°C on a sterile filter
paper placed over 1.5 ml of a tobacco cell feeder layer overlaid on
1/10 P medium (1/10 strength MS inorganic salts and organic
addenda without casein as in Jarret et al. (1980), 30 g/l sucrose
20 and 8.0 g/l agar). Following co-culture, the explants are
transferred to full strength P-1 medium for callus induction,
composed of MS inorganic salts, organic additions as in Jarret et
al. (1980), with the exception of casein, 5.0 mg/l zeatin riboside
(ZR), and 0.10 mg/l naphthaleneacetic acid NAA (Jarret et al.,
25 1980a, 1980b). Carbenicillin (500 mg/l) and cefotaxime (100 mg/L)
are included to inhibit bacterial growth, and 100 mg/l
kanamycin is added to select for transformed cells.
Transformed potato plants expressing the patatin promoter -
CTP/ADPglucose pyrophosphorylase - NOS gene show an
30 increased starch content in the tuber.

After 4 weeks, the explants are transferred to medium
of the same composition, but with 0.3 mg/l gibberellic acid (GA3)

5 replacing the NAA (Jarret et al., 1981) to promote shoot formation. Shoots begin to develop approximately 2 weeks after transfer to shoot induction medium. These shoots are excised and transferred to vials of PM medium for rooting. After about 4 weeks on the rooting medium, the plants are transferred to soil and are gradually hardened off. Shoots are tested for kanamycin resistance conferred by the enzyme neomycin phospho-
10 transferase II, by placing the shoots on PM medium for rooting, which contains 50 mg/L kanamycin, to select for transformed cells.

Russet Burbank Williams plants regenerated in culture were transplanted into 6 inch (~15.24 cm) pots and were grown to maturity under greenhouse conditions. Tubers were harvested and were allowed to suberize at room temperature for two days.
15 All tubers greater than 2 cm. in length were collected and stored at 9°C under high humidity.

Specific gravity (SG) was determined 3 days after harvest for the largest 2 or 3 tubers from each plant, with typical weights being 20-40 grams per tuber. Specific gravity calculations were performed by the weight in air less weight in water method, where $SG = \text{weight in air} / (\text{weight in air} - \text{weight in water})$. Calculations for percent starch and percent dry matter based on SG were according to the following formulas (von Scheelem, 1937):
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$$\begin{aligned}\% \text{ starch} &= 17.546 + (199.07)(SG - 1.0988) \\ \% \text{ dry matter} &= 24.182 + (211.04)(SG - 1.0988).\end{aligned}$$

Western blot analysis was performed on protein extracted from fresh, center sections of tuber tissue as described for tomato leaf tissue. Starch analysis was performed on similar
30 fresh tuber sections as described (Lin, 1988a). Briefly,

approximately 300 mg. center sections were cut, placed in 1.5 ml centrifuge tubes, and frozen on dry ice. The tissue was then dried to a stable weight in a Savant Speed-Vac Concentrator, and final dry weight was determined. Starch content was determined using approximately 60 mg. of dry material from each tuber. Soluble sugars were first removed by extracting three times with 1 ml of 80% ethanol at 70°C, for 20 minutes per treatment. After the final incubation, all remaining ethanol was removed by desiccation in a Speed Vac Concentrator. The solid material was resuspended in 400 μ l 0.2 M potassium hydroxide, ground, and then incubated for 30 minutes at 100°C to solubilize the starch. The solutions were cooled and neutralized by addition of 80 μ l 1N acetic acid. Starch was degraded to glucose by treatment with 14.8 units of pancreatic alpha-amylase (Sigma Chemical, St. Louis) for 30 minutes at 37°C, followed by 10 units of amyloglucosidase (Sigma Chemical, St. Louis) for 60 minutes at 55°C. Glucose released by the enzymatic digestions was measured using the Sigma Chemical (St. Louis) hexokinase kit.

Western blot and quantitative starch analyses were performed on center cuts from tubers generated under standard greenhouse conditions. Tubers from potato plants expressing *E. coli* ADPGPP contain on average 26.4% higher levels of starch than controls. The range of individual data points shows that two distinct populations exist with respect to starch content. One population, represented by the control tubers, range in starch content from 10.2% up to 15%, with an average starch content of 12.67%. The second population represents expressors of *E. coli* ADPGPP, which range in starch content from 12.1% up to 19.1%, with an average of 16%. The observed increase in starch content correlated with expression levels of *E. coli* ADPGPP,

demonstrating that this expression leads to an increase in starch content in potato tubers.

5 Specific gravity was determined for the largest 2 or 3 tubers from each of 36 independent transformants by the weight in air less weight in water method (Kleinkopf, 1987). The data show that tubers expressing *E. coli* ADPGPP had a significant increase in specific gravity compared to controls. On average, the specific gravity increased from 1.068 in control tubers up to 1.088 in transgenic tubers (Table 1a), with the best lines averaging specific gravities of about 1.100. Specific gravity values varied among tubers of the same plant, as well as between tubers from different plants, as expected. However, only lines expressing *E. coli* ADPGPP produced tubers with elevated specific gravities, and these increases roughly correlated with the levels of *glgC16* expression. Starch and dry matter content increased on average 35.0% and 23.9% respectively in tubers expressing *E. coli* ADPGPP, with the best lines containing approximately 59.3% and 40.6% increases, respectively.

15 The starch content determined by the glucose method for a total of 26 potato lines was compared with the starch content calculated for these same tubers using specific gravity measurements. The levels of starch as calculated from specific gravity were in good agreement with that determined directly (Table 1b). For example, tubers expressing *E. coli* ADPGPP contained 16.01% starch as determined by quantitative analysis versus 16.32% as determined by specific gravity. When increases in individual lines were examined, the experimentally determined starch content strongly correlated with the observed increase in dry matter (and expression of the *glgC16* gene). Therefore, the observed increase in dry matter content in tubers

expressing *E. coli* ADPGPP is largely due to the increased deposition of starch.

Table 1

5

a)	Average	Average	Average
	<u>Specific Gravity</u>	<u>% Starch</u>	<u>% Dry Matter</u>
<i>E.coli</i> ADPGPP+ (15)	1.088 (0.012)	15.40	21.90
Controls (21)	1.068 (0.010)	11.41	17.68

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The number of plants tested is indicated in parenthesis, with two or three tubers per plant being weighed. Sample standard deviation follows specific gravity (in parenthesis). Percent starch and dry matter were calculated from the average specific gravity as described. Controls consist of a combination of tubers transformed to contain only the DNA vector, without the *glgC16* gene, and tubers from the *glgC16* transformation event which do not express *E. coli* ADPGPP.

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b)	Avg % Starch	Avg % Starch
	<u>Specific Gravity</u>	<u>Enzymatic</u>
<i>E.coli</i> ADPGPP+ (11)	16.32 (1.47)	16.01 (2.00)
Controls (15)	11.96 (1.37)	12.67 (1.33)

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Average values for percent starch determined experimentally by enzymatic degradation to starch content and calculated from specific gravity measurements. Sample standard deviations are in parenthesis. Differences between *E.coli* ADPGPP+ and controls, calculated by specific gravity or enzymatic methods, are significant at >0.005 level of significance by the Student T-test.

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Example 4

The enzyme ADPGPP is encoded by a single gene in *E. coli* (*glgC*), whose active form functions as a homotetramer (Preiss, 1984), while the plant enzyme is a heterotetramer encoded by at least two different genes (Copeland and Preiss, 1981). Both *E. coli* and plant ADPGPP's are subject to tight

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regulation, with the bacterial enzyme being activated by fructose 1,6-bisphosphate and inhibited by AMP (Preiss, 1984), while the plant enzymes are activated by 3-phosphoglycerate and inhibited by P_i (Copeland and Preiss, 1981; Preiss, 1984). Several mutants of *E. coli* ADPGPP have been characterized and the kinetic properties of a few are summarized and compared in Table 2. (Romeo, T. and Preiss, J., 1989).

Table 2

Strain	Glycogen accumulation (mg/g cells)	Fructose 1,6-biphosphate $A_{0.5}$ (μ M)	AMP $I_{0.5}$ (μ M)
wild type	20	68	75
SG5	35	22	170
CL1136	74	5.2	680
618	70	15	860

It has been demonstrated that expression of the *glgC16* variant, found in *E. coli* strain 618, leads to enhanced starch biosynthesis in plant cells. Expression of other bacterial ADPGPP enzymes in plant cells also enhance starch content.

Expression of the wild type *glgC* gene also leads to increased starch content. The wild type *glgC* gene, contained on an *E. coli* genomic clone designated pOP12 (Okita et al., 1981) was isolated in a manner similar to that described for the isolation of the *glgC16* gene described in Example 1. Briefly, an *Nco*I site was introduced at the 5' translational start site and a *Sac*I site was introduced just 3' of the termination codon by the PCR reaction using the QSP3 and QSM10 primers described in Example 1. The resultant *Nco*I-*Sac*I fragment was ligated into the vector pMON20102 (described in Example 1) previously

digested with *Nco*I and *Sac*I, giving the plasmid pMON16937. The PS*su-glgC* chimeric gene was constructed by ligating an *Xho*I-*Bgl*II restriction fragment containing the *Ssu*1A promoter (Timko et al., 1985), the *Bgl*II-*Sac*I fragment from pMON16937 comprising the CTP1-*glgC* gene, and the plant transformation vector pMON977 digested with *Xho*I and *Sac*I, to form pMON16938 (Figure 8). The pMON977 plasmid contains the following well characterized DNA segments (Figure 9). First, the 0.93 Kb fragment isolated from transposon Tn7 which encodes bacterial spectinomycin/streptomycin resistance (Spc/Str), and is a determinant for selection in *E. coli* and *Agrobacterium tumefaciens* (Fling et al., 1985). This is joined to the chimeric kanamycin resistance gene engineered for plant expression to allow selection of the transformed tissue. The chimeric gene consists of the 0.35 Kb cauliflower mosaic virus 35S promoter (P-35S)(Odell et al., 1985), the 0.83 Kb neomycin phosphotransferase typeII gene (NPTII), and the 0.26 Kb 3'-nontranslated region of the nopaline synthase gene (NOS 3') (Fraley et al., 1983). The next segment is the 0.75 Kb origin of replication from the RK2 plasmid (ori-V) (Stalker et al., 1981). This is joined to the 33.1 Kb *Sal*I to *Pvu*I fragment from pBR322 which provides the origin of replication for maintenance in *E. coli* (ori-322), and the *bom* site for the conjugational transfer into the *Agrobacterium tumefaciens* cells. Next is the 0.36 Kb *Pvu*I to *Bcl*I fragment from the pTiT37 plasmid, which contains the nopaline-type T-DNA right border region (Fraley et al., 1985). The last segment is the expression cassette consisting of the 0.65 Kb cauliflower mosaic virus (CaMV) 35S promoter enhanced by duplication of the promoter sequence (P-E35S) (Kay et al., 1987), a synthetic multilinker with several unique cloning sites, and the 0.7 Kb 3' nontranslated region of the pea *rbcS-E9* gene (E9 3') (Coruzzi et al., 1984; Morelli et al., 1985). The plasmid was

mated into *Agrobacterium tumefaciens* strain ABI, using the triparental mating system, and used to transform *Lycopersicon esculentum* cv. UC82B.

5 Tomato plant cells are transformed utilizing the *Agrobacterium* strains described above generally by the method as described in McCormick et al. (1986). In particular, cotyledons are obtained from 7-8 day old seedlings. The seeds are surface sterilized for 20 minutes in 30% Clorox bleach and are germinated in Plantcons boxes on Davis germination media. 10 Davis germination media is comprised of 4.3g/l MS salts, 20g/l sucrose and 10 mls/l Nitsch vitamins, pH5.8. The Nitsch vitamin solution is comprised of 100mg/l myo-inositol, 5mg/l nicotinic acid, 0.5mg/l pyridoxine HCl, 0.5mg/l thiamine HCl, 0.05mg/l folic acid, 0.05mg/l biotin, 2mg/l glycine. The seeds are 15 allowed to germinate for 7-8 days in the growth chamber at 25°C, 40% humidity under cool white lights with an intensity of 80 einsteins m⁻²s⁻¹. The photoperiod is 16 hours of light and 8 hours of dark.

20 Once germination has occurred, the cotyledons are explanted using a #15 feather blade by cutting away the apical meristem and the hypocotyl to create a rectangular explant. These cuts at the short ends of the germinating cotyledon increase the surface area for infection. The explants are bathed in sterile Davis regeneration liquid to prevent desiccation. Davis 25 regeneration media is composed of 1X MS salts, 3% sucrose, 1X Nitsch vitamins, 2.0 mg/l zeatin, pH 5.8. This solution is autoclaved with 0.8% Noble Agar.

30 The cotyledons are pre-cultured on "feeder plates" composed of Calgene media containing no antibiotics. Calgene media is composed of 4.3g/l MS salts, 30g/l sucrose, 0.1g/l myo-inositol, 0.2g/l KH₂PO₄, 1.45mls/l of a 0.9mg/ml solution of thiamine HCl, 0.2mls of a 0.5mg/ml solution of kinetin and

0.1ml of a 0.2mg/ml solution of 2,4 D, this solution is adjusted to pH 6.0 with KOH. These plates are overlaid with 1.5-2.0 mls of tobacco suspension cells (TXD's) and a sterile Whatman filter which is soaked in 2COO5K media. 2COO5K media is composed of 4.3g/l Gibco MS salt mixture, 1ml B5 vitamins (1000X stock), 30g/l sucrose, 2mls/l PCPA from 2mg/ml stock, and 10 μ l/l kinetin from 0.5mg/ml stock. The cotyledons are cultured for 1 day in a growth chamber at 25°C under cool white lights with a light intensity of 40-50 einsteins m⁻²s⁻¹ with a continuous light photoperiod.

Cotyledons are then inoculated with a log phase solution of *Agrobacterium* containing the plasmid pMON16938. The concentration of the *Agrobacterium* is approximately 5x10⁸ cells/ml. The cotyledons are allowed to soak in the bacterial solution for six minutes and are then blotted to remove excess solution on sterile Whatman filter disks and are subsequently replaced to the original feeder plate where they are allowed to co-culture for 2 days. After the two days, cotyledons are transferred to selection plates containing Davis regeneration media with 2mg/l zeatin riboside, 500 μ g/ml carbenicillin, and 100 μ g/ml kanamycin. After 2-3 weeks, cotyledons with callus and/or shoot formation are transferred to fresh Davis regeneration plates containing carbenicillin and kanamycin at the same levels. The experiment is scored for transformants at this time. The callus tissue is subcultured at regular 3 week intervals and any abnormal structures are trimmed so that the developing shoot buds will continue to regenerate. Shoots develop within 3-4 months.

Once shoots develop, they are excised cleanly from callus tissue and are planted on rooting selection plates. These plates contain 0.5X MSO containing 50 μ g/ml kanamycin and 500 μ g/ml carbenicillin. These shoots form roots on the selection

media within two weeks. If no shoots appear after 2 weeks, shoots are trimmed and replanted on the selection media. Shoot cultures are incubated in percivals at a temperature of 22°C. Shoots with roots are then potted when roots are about 2cm in length. The plants are hardened off in a growth chamber at 21°C with a photoperiod of 18 hours light and 6 hours dark for 2-3 weeks prior to transfer to a greenhouse. In the greenhouse, the plants are grown at a temperature of 26°C during the day and 21°C during the night. The photoperiod is 13 hours light and 11 hours dark and allowed to mature.

Transgenic tomato plants transformed with pMON16938 were generated and screened by Western blot analysis for the *glgC* gene product. For Western blot analysis, proteins were extracted from leaf or stem tissue by grinding 1:1 in 100 mM Tris pH7.5, 35 mM KCl, 5 mM dithiothreitol, 5 mM ascorbate, 1 mM EDTA, 1 mM benzamidine, and 20% glycerol. The protein concentration of the extract was determined using the Pierce BCA method, and proteins were separated on 3-17% SDS polyacrylamide gels. *E. coli* ADPGPP was detected using goat antibodies raised against purified *E. coli* ADPGPP and alkaline phosphatase conjugated rabbit anti-goat antibodies (Promega, Madison, WI). In most plants expressing wild type *E. coli* ADPGPP, levels of *E. coli* ADPGPP were on 0.1% of the total extractable protein. For starch analysis, single leaf punches were harvested during late afternoon from 3-4 different, young, fully-expanded leaves per greenhouse grown plant. The leaf punches from each plant were combined and fresh weights were determined using a Mettler analytical balance. Total fresh weight per sample ranged from 60-80 mg. Soluble sugars were first removed by extracting three times with 1 ml of 80% ethanol at 70°C for 20 minutes per treatment. After the final incubation, all remaining ethanol was removed by desiccation in a Speed Vac Concentrator. The solid material was resuspended in 400 µl 0.2 M potassium hydroxide, ground, and then incubated for 30

minutes at 100°C to solubilize the starch. The solutions were cooled and then neutralized by addition of 80 µl 1N acetic acid. Starch was degraded to glucose by treatment with 14.8 units of pancreatic alpha-amylase (Sigma Chemical, St. Louis) for 30 minutes at 37°C, followed by 10 units of amyloglucosidase (Sigma Chemical, St. Louis) for 60 minutes at 55°C. Glucose released by the enzymatic digestions was measured using the Sigma Chemical (St. Louis) hexokinase kit, and these values were used to calculate starch content.

Leaves from tomato plants expressing the *glgC* gene from the *Ssu* promoter contain on average 29% higher levels of starch than controls, with the best line showing a 107% increase (Table 3).

Table 3

	Average <u>% Starch</u>	Standard <u>Deviation</u>
<i>E. coli</i> ADPGPP+ (7)	4.54	2.1
Controls (8)	3.52	1.9

The number of lines screened are in parentheses. Thus, other ADPGPP's with different kinetic properties are also effective in increasing starch content in transgenic plants. It should be noted that high level expression of unregulated ADPGPP mutants in leaf tissue is undesirable since it will cause adverse effects on growth and development of the plants. In fact, use of the *glgC16* gene in place of *glgC* in the above experiments did not result in regeneration of transformants expressing high levels of the *glgC16* gene product.

To express *glgC* from the patatin promoter, the same *Bgl*III-*Sac*I CTP1-*glgC* fragment from pMON16937 and a *Hind*III-*Bam*HI fragment containing the patatin promoter from the

plasmid pBI241.3 were ligated into the binary vector pMON10098 (Figure 11), digested with *Hind*III and *Sac*I, to give the plasmid pMON16950 (Figure 10). The pBI241.3 plasmid contains the patatin-1 promoter segment comprising from the *Acc*I site at 1323 to the *Dra*I site at 22389 [positions refer to the sequence in Bevan et al., 1986] with a *Hind*III linker added at the latter position. The pMON10098 plasmid contains the following DNA regions, moving clockwise around Figure 11. 1) The chimeric kanamycin resistance gene engineered for plant expression to allow selection of the transformed tissue. The chimeric gene consists of the 0.35 Kb cauliflower mosaic virus 35S promoter (P-35S) (Odell et al., 1985), the 0.83 Kb neomycin phosphotransferase type II gene (KAN), and the 0.26 Kb 3'-nontranslated region of the nopaline synthase gene (NOS 3') (Fraley et al., 1983); 2) The 0.45 Kb *Cla*I to the *Dra*I fragment from the pTi15955 octopine Ti plasmid, which contains the T-DNA left border region (Barker et al., 1983); 3) The 0.75 Kb segment containing the origin of replication from the RK2 plasmid (ori-V) (Stalker et al., 1981); 4) The 3.0 Kb *Sal*I to *Pst*I segment of pBR322 which provides the origin of replication for maintenance in *E. coli* (ori-322), and the *bom* site for the conjugational transfer into the *Agrobacterium tumefaciens* cells; 5) The 0.93 Kb fragment isolated from transposon Tn7 which encodes bacterial spectinomycin/streptomycin resistance (Spc/Str) (Fling et al., 1985), and is a determinant for selection in *E. coli* and *Agrobacterium tumefaciens*; 6) The 0.36 Kb *Pvu*I to *Bcl*I fragment from the pTiT37 plasmid, which contains the nopaline-type T-DNA right border region (Fraley et al., 1985); and 7) The last segment is the expression cassette consisting of the 0.65 Kb cauliflower mosaic virus (CaMV) 35S promoter enhanced by duplication of the promoter sequence (P-E35S) (Kay et al., 1987), a synthetic multilinker with several unique cloning sites, and the 0.7 Kb 3'

nontranslated region of the pea *rbcS*-E9 gene (E9 3') (Coruzzi et al., 1984; Morelli et al., 1985). The plasmid was mated into *Agrobacterium tumefaciens* strain ABI, using the triparental mating system, and used to transform Russet Burbank line Williams 82. Expression of *glgC* from the patatin promoter (pMON16950) in potato also results in enhanced starch content in tubers.

In a manner similar to that described for the wild type *glgC* gene and for the *glgC16* mutant gene, the mutant *glgC*-SG5 was also expressed in plants and results in an enhancement of starch content.

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANT: Kishore, Ganesh M.
- (ii) TITLE OF INVENTION: Increased Starch Content in Plants
- (iii) NUMBER OF SEQUENCES: 23
- (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: Monsanto Co.
 - (B) STREET: 700 Chesterfield Village Parkway
 - (C) CITY: St. Louis
 - (D) STATE: Missouri
 - (E) COUNTRY: USA
 - (F) ZIP: 63198
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.25
- (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER:
 - (B) FILING DATE:
 - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: McBride, Thomas P.
 - (B) REGISTRATION NUMBER: 32706
 - (C) REFERENCE/DOCKET NUMBER: 38-21(10530)A
- (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: (314) 537-7357
 - (B) TELEFAX: (314) 537-6047

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 1296 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

- (ix) FEATURE:
 - (A) NAME/KEY: CDS
 - (B) LOCATION: 1..1293

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

ATG	GTT	AGT	TTA	GAG	AAG	AAC	GAT	CAC	TTA	ATG	TTG	GCG	CGC	CAG	CTG	48
Met	Val	Ser	Leu	Glu	Lys	Asn	Asp	His	Leu	Met	Leu	Ala	Arg	Gln	Leu	
1				5				10						15		
CCA	TTG	AAA	TCT	GTT	GCC	CTG	ATA	CTG	GCG	GGA	GGA	CGT	GGT	ACC	CGC	96

Pro	Leu	Lys	Ser 20	Val	Ala	Leu	Ile	Leu 25	Ala	Gly	Gly	Arg	Gly 30				
CTG	AAG	GAT	TTA	ACC	AAT	AAG	CGA	GCA	AAA	CCG	GCC	GTA	CAC	TTC	GGC	144	
Leu	Lys	Asp 35	Leu	Thr	Asn	Lys	Arg 40	Ala	Lys	Pro	Ala	Val 45	His	Phe	Gly		
GGT	AAG	TTC	CGC	ATT	ATC	GAC	TTT	GCG	CTG	TCT	AAC	TGC	ATC	AAC	TCC	192	
Gly	Lys 50	Phe	Arg	Ile	Ile	Asp 55	Phe	Ala	Leu	Ser	Asn 60	Cys	Ile	Asn	Ser		
GGG	ATC	CGT	CGT	ATG	GGC	GTG	ATC	ACC	CAG	TAC	CAG	TCC	CAC	ACT	CTG	240	
Gly 65	Ile	Arg	Arg	Met	Gly 70	Val	Ile	Thr	Gln	Tyr 75	Gln	Ser	His	Thr	Leu 80		
GTG	CAG	CAC	ATT	CAG	CGC	GGC	TGG	TCA	TTC	TTC	AAT	GAA	GAA	ATG	AAC	288	
Val	Gln	His	Ile	Gln 85	Arg	Gly	Trp	Ser	Phe 90	Phe	Asn	Glu	Glu	Met 95	Asn		
GAG	TTT	GTC	GAT	CTG	CTG	CCA	GCA	CAG	CAG	AGA	ATG	AAA	GGG	GAA	AAC	336	
Glu	Phe	Val	Asp 100	Leu	Leu	Pro	Ala	Gln 105	Gln	Arg	Met	Lys	Gly 110	Glu	Asn		
TGG	TAT	CGC	GGC	ACC	GCA	GAT	GCG	GTC	ACC	CAA	AAC	CTC	GAC	ATT	ATC	384	
Trp	Tyr	Arg 115	Gly	Thr	Ala	Asp	Ala	Val	Thr	Gln	Asn	Leu	Asp	Ile	Ile		
CGT	CGT	TAT	AAA	GCG	GAA	TAC	GTG	GTG	ATC	CTG	GCG	GGC	GAC	CAT	ATC	432	
Arg	Arg 130	Tyr	Lys	Ala	Glu	Tyr 135	Val	Val	Ile	Leu	Ala	Gly	Asp	His	Ile		
TAC	AAG	CAA	GAC	TAC	TCG	CGT	ATG	CTT	ATC	GAT	CAC	GTC	GAA	AAA	GGT	480	
Tyr 145	Lys	Gln	Asp	Tyr	Ser 150	Arg	Met	Leu	Ile	Asp 155	His	Val	Glu	Lys	Gly 160		
GTA	CGT	TGT	ACC	GTT	GTT	TGT	ATG	CCA	GTA	CCG	ATT	GAA	GAA	GCC	TCC	528	
Val	Arg	Cys	Thr 165	Val	Val	Cys	Met	Pro	Val 170	Pro	Ile	Glu	Glu	Ala 175	Ser		
GCA	TTT	GGC	GTT	ATG	GCG	GTT	GAT	GAG	AAC	GAT	AAA	ACT	ATC	GAA	TTC	576	
Ala	Phe	Gly 180	Val	Met	Ala	Val	Asp	Glu 185	Asn	Asp	Lys	Thr 190	Ile	Glu	Phe		
GTG	GAA	AAA	CCT	GCT	AAC	CCG	CCG	TCA	ATG	CCG	AAC	GAT	CCG	AGC	AAA	624	
Val	Glu	Lys 195	Pro	Ala	Asn	Pro	Pro 200	Ser	Met	Pro	Asn	Asp 205	Pro	Ser	Lys		
TCT	CTG	GCG	AGT	ATG	GGT	ATC	TAC	GTC	TTT	GAC	GCC	GAC	TAT	CTG	TAT	672	
Ser	Leu 210	Ala	Ser	Met	Gly 215	Ile	Tyr	Val	Phe	Asp	Ala	Asp 220	Tyr	Leu	Tyr		
GAA	CTG	CTG	GAA	GAA	GAC	GAT	CGC	GAT	GAG	AAC	TCC	AGC	CAC	GAC	TTT	720	
Glu	Leu	Leu	Glu	Glu	Asp 230	Asp	Arg	Asp	Glu	Asn 235	Ser	Ser	His	Asp	Phe 240		
GGC	AAA	GAT	TTG	ATT	CCC	AAG	ATC	ACC	GAA	GCC	GGT	CTG	GCC	TAT	GCG	768	
Gly	Lys	Asp	Leu	Ile 245	Pro	Lys	Ile	Thr	Glu 250	Ala	Gly	Leu	Ala	Tyr 255	Ala		
CAC	CCG	TTC	CCG	CTC	TCT	TGC	GTA	CAA	TCC	GAC	CCG	GAT	GCC	GAG	CCG	816	
His	Pro	Phe	Pro 260	Leu	Ser	Cys	Val 265	Gln	Ser	Asp	Pro	Asp 270	Ala	Glu	Pro		
TAC	TGG	CGC	GAT	GTG	GGT	ACG	CTG	GAA	GCT	TAC	TGG	AAA	GCG	AAC	CTC	864	

77

Tyr	Trp	Arg	Asp	Val	Gly	Thr	Leu	Glu	Ala	Tyr	Trp	Lys	Ala	P		
		275					280					285				
GAT	CTG	GCC	TCT	GTG	GTG	CCG	AAA	CTG	GAT	ATG	TAC	GAT	CGC	AAT	TGG	912
Asp	Leu	Ala	Ser	Val	Val	Pro	Lys	Leu	Asp	Met	Tyr	Asp	Arg	Asn	Trp	
	290					295					300					
CCA	ATT	CGC	ACC	TAC	AAT	GAA	TCA	TTA	CCG	CCA	GCG	AAA	TTC	GTG	CAG	960
Pro	Ile	Arg	Thr	Tyr	Asn	Glu	Ser	Leu	Pro	Pro	Ala	Lys	Phe	Val	Gln	
305					310				315					320		
GAT	CGC	TCC	GGT	AGC	CAC	GGG	ATG	ACC	CTT	AAC	TCA	CTG	GTT	TCC	GGC	1008
Asp	Arg	Ser	Gly	Ser	His	Gly	Met	Thr	Leu	Asn	Ser	Leu	Val	Ser	Gly	
				325					330					335		
GGT	TGT	GTG	ATC	TCC	GGT	TCG	GTG	GTG	GTG	CAG	TCC	GTT	CTG	TTC	TCG	1056
Gly	Cys	Val	Ile	Ser	Gly	Ser	Val	Val	Val	Gln	Ser	Val	Leu	Phe	Ser	
			340					345					350			
CGC	GTT	CGC	GTG	AAT	TCA	TTC	TGC	AAC	ATT	GAT	TCC	GCC	GTA	TTG	TTA	1104
Arg	Val	Arg	Val	Asn	Ser	Phe	Cys	Asn	Ile	Asp	Ser	Ala	Val	Leu	Leu	
		355					360					365				
CCG	GAA	GTA	TGG	GTA	GGT	CGC	TCG	TGC	CGT	CTG	CGC	CGC	TGC	GTC	ATC	1152
Pro	Glu	Val	Trp	Val	Gly	Arg	Ser	Cys	Arg	Leu	Arg	Arg	Cys	Val	Ile	
	370					375					380					
GAT	CGT	GCT	TGT	GTT	ATT	CCG	GAA	GGC	ATG	GTG	ATT	GGT	GAA	AAC	GCA	1200
Asp	Arg	Ala	Cys	Val	Ile	Pro	Glu	Gly	Met	Val	Ile	Gly	Glu	Asn	Ala	
385					390					395					400	
GAG	GAA	GAT	GCA	CGT	CGT	TTC	TAT	CGT	TCA	GAA	GAA	GGC	ATC	GTG	CTG	1248
Glu	Glu	Asp	Ala	Arg	Arg	Phe	Tyr	Arg	Ser	Glu	Glu	Gly	Ile	Val	Leu	
				405				410						415		
GTA	ACG	CGC	GAA	ATG	CTA	CGG	AAG	TTA	GGG	CAT	AAA	CAG	GAG	CGA		1293
Val	Thr	Arg	Glu	Met	Leu	Arg	Lys	Leu	Gly	His	Lys	Gln	Glu	Arg		
			420					425					430			
TAA																1296

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 431 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Met Val Ser Leu Glu Lys Asn Asp His Leu Met Leu Ala Arg Gln Leu
 1 5 10

Pro Leu Lys Ser Val Ala Leu Ile Leu Ala Gly Gly Arg Gly Thr Arg
 20 25 30

Leu Lys Asp Leu Thr Asn Lys Arg Ala Lys Pro Ala Val His Phe Gly
 35 40 45

Gly Lys Phe Arg Ile Ile Asp Phe Ala Leu Ser Asn Cys Ile Asn Ser
 50 55 60

78

Gly Ile Arg Arg Met Gly Val Ile Thr Gln Tyr Gln Ser His Tr 80
 65 70 75
 Val Gln His Ile Gln Arg Gly Trp Ser Phe Phe Asn Glu Glu Met Asn
 85 90 95
 Glu Phe Val Asp Leu Leu Pro Ala Gln Gln Arg Met Lys Gly Glu Asn
 100 105 110
 Trp Tyr Arg Gly Thr Ala Asp Ala Val Thr Gln Asn Leu Asp Ile Ile
 115 120 125
 Arg Arg Tyr Lys Ala Glu Tyr Val Val Ile Leu Ala Gly Asp His Ile
 130 135 140
 Tyr Lys Gln Asp Tyr Ser Arg Met Leu Ile Asp His Val Glu Lys Gly
 145 150 155 160
 Val Arg Cys Thr Val Val Cys Met Pro Val Pro Ile Glu Glu Ala Ser
 165 170 175
 Ala Phe Gly Val Met Ala Val Asp Glu Asn Asp Lys Thr Ile Glu Phe
 180 185 190
 Val Glu Lys Pro Ala Asn Pro Pro Ser Met Pro Asn Asp Pro Ser Lys
 195 200 205
 Ser Leu Ala Ser Met Gly Ile Tyr Val Phe Asp Ala Asp Tyr Leu Tyr
 210 215 220
 Glu Leu Leu Glu Glu Asp Asp Arg Asp Glu Asn Ser Ser His Asp Phe
 225 230 235 240
 Gly Lys Asp Leu Ile Pro Lys Ile Thr Glu Ala Gly Leu Ala Tyr Ala
 245 250 255
 His Pro Phe Pro Leu Ser Cys Val Gln Ser Asp Pro Asp Ala Glu Pro
 260 265 270
 Tyr Trp Arg Asp Val Gly Thr Leu Glu Ala Tyr Trp Lys Ala Asn Leu
 275 280 285
 Asp Leu Ala Ser Val Val Pro Lys Leu Asp Met Tyr Asp Arg Asn Trp
 290 295 300
 Pro Ile Arg Thr Tyr Asn Glu Ser Leu Pro Pro Ala Lys Phe Val Gln
 305 310 315 320
 Asp Arg Ser Gly Ser His Gly Met Thr Leu Asn Ser Leu Val Ser Gly
 325 330 335
 Gly Cys Val Ile Ser Gly Ser Val Val Val Gln Ser Val Leu Phe Ser
 340 345 350
 Arg Val Arg Val Asn Ser Phe Cys Asn Ile Asp Ser Ala Val Leu Leu
 355 360 365
 Pro Glu Val Trp Val Gly Arg Ser Cys Arg Leu Arg Arg Cys Val Ile
 370 375 380
 Asp Arg Ala Cys Val Ile Pro Glu Gly Met Val Ile Gly Glu Asn Ala
 385 390 395 400

79

Glu Glu Asp Ala Arg Arg Phe Tyr Arg Ser Glu Glu Gly Ile Val
 405 410 41
 Val Thr Arg Glu Met Leu Arg Lys Leu Gly His Lys Gln Glu Arg
 420 425 430

(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 1296 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

- (ix) FEATURE:
 (A) NAME/KEY: CDS
 (B) LOCATION: 1..1293

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

ATG GTT AGT TTA GAG AAG AAC GAT CAC TTA ATG TTG GCG CGC CAG CTG	48
Met Val Ser Leu Glu Lys Asn Asp His Leu Met Leu Ala Arg Gln Leu	
1 5 10 15	
CCA TTG AAA TCT GTT GCC CTG ATA CTG GCG GGA GGA CGT GGT ACC CGC	96
Pro Leu Lys Ser Val Ala Leu Ile Leu Ala Gly Gly Arg Gly Thr Arg	
20 25 30	
CTG AAG GAT TTA ACC AAT AAG CGA GCA AAA CCG GCC GTA CAC TTC GGC	144
Leu Lys Asp Leu Thr Asn Lys Arg Ala Lys Pro Ala Val His Phe Gly	
35 40 45	
GGT AAG TTC CGC ATT ATC GAC TTT GCG CTG TCT AAC TGC ATC AAC TCC	192
Gly Lys Phe Arg Ile Ile Asp Phe Ala Leu Ser Asn Cys Ile Asn Ser	
50 55 60	
GGG ATC CGT CGT ATG GGC GTG ATC ACC CAG TAC CAG TCC CAC ACT CTG	240
Gly Ile Arg Arg Met Gly Val Ile Thr Gln Tyr Gln Ser His Thr Leu	
65 70 75 80	
GTG CAG CAC ATT CAG CGC GGC TGG TCA TTC TTC AAT GAA GAA ATG AAC	288
Val Gln His Ile Gln Arg Gly Trp Ser Phe Phe Asn Glu Glu Met Asn	
85 90 95	
GAG TTT GTC GAT CTG CTG CCA GCA CAG CAG AGA ATG AAA GGG GAA AAC	336
Glu Phe Val Asp Leu Leu Pro Ala Gln Gln Arg Met Lys Gly Glu Asn	
100 105 110	
TGG TAT CGC GGC ACC GCA GAT GCG GTC ACC CAA AAC CTC GAC ATT ATC	384
Trp Tyr Arg Gly Thr Ala Asp Ala Val Thr Gln Asn Leu Asp Ile Ile	
115 120 125	
CGT CGT TAT AAA GCG GAA TAC GTG GTG ATC CTG GCG GGC GAC CAT ATC	432
Arg Arg Tyr Lys Ala Glu Tyr Val Val Ile Leu Ala Gly Asp His Ile	
130 135 140	
TAC AAG CAA GAC TAC TCG CGT ATG CTT ATC GAT CAC GTC GAA AAA GGT	480
Tyr Lys Gln Asp Tyr Ser Arg Met Leu Ile Asp His Val Glu Lys Gly	
145 150 155 160	

80

GTA Val	CGT Arg	TGT Cys	ACC Thr	GTT Val 165	GTT Val	TGT Cys	ATG Met	CCA Pro	GTA Val 170	CCG Pro	ATT Ile	GAA Glu	GAA Glu	G A 175		
GCA Ala	TTT Phe	GGC Gly	GTT Val 180	ATG Met	GCG Ala	GTT Val	GAT Asp	GAG Glu 185	AAC Asn	GAT Asp	AAA Lys	ACT Thr	ATC Ile 190	GAA Glu	TTC Phe	576
GTG Val	GAA Glu	AAA Lys 195	CCT Pro	GCT Ala	AAC Asn	CCG Pro	CCG Pro 200	TCA Ser	ATG Met	CCG Pro	AAC Asn	GAT Asp 205	CCG Pro	AGC Ser	AAA Lys	624
TCT Ser	CTG Leu 210	GCG Ala	AGT Ser	ATG Met	GGT Gly	ATC Ile 215	TAC Tyr	GTC Val	TTT Phe	GAC Asp 220	GCC Ala	GAC Asp	TAT Tyr	CTG Leu	TAT Tyr	672
GAA Glu 225	CTG Leu	CTG Leu	GAA Glu	GAA Glu	GAC Asp 230	GAT Asp	CGC Arg	GAT Asp	GAG Glu	AAC Asn 235	TCC Ser	AGC Ser	CAC His	GAC Asp	TTT Phe 240	720
GGC Gly	AAA Lys	GAT Asp	TTG Leu	ATT Ile 245	CCC Pro	AAG Lys	ATC Ile	ACC Thr	GAA Glu 250	GCC Ala	GGT Gly	CTG Leu	GCC Ala	TAT Tyr 255	GCG Ala	768
CAC His	CCG Pro	TTC Phe	CCG Pro 260	CTC Leu	TCT Ser	TGC Cys	GTA Val	CAA Gln 265	TCC Ser	GAC Asp	CCG Pro	GAT Asp	GCC Ala 270	GAG Glu	CCG Pro	816
TAC Tyr	TGG Trp	CGC Arg 275	GAT Asp	GTG Val	GGT Gly	ACG Thr	CTG Leu 280	GAA Glu	GCT Ala	TAC Tyr	TGG Trp	AAA Lys 285	GCG Ala	AAC Asn	CTC Leu	864
GAT Asp	CTG Leu 290	GCC Ala	TCT Ser	GTG Val	GTG Val	CCG Pro 295	GAA Glu	CTG Leu	GAT Asp	ATG Met	TAC Tyr 300	GAT Asp	CGC Arg	AAT Asn	TGG Trp	912
CCA Pro 305	ATT Ile	CGC Arg	ACC Thr	TAC Tyr	AAT Asn 310	GAA Glu	TCA Ser	TTA Leu	CCG Pro	CCA Pro 315	GCG Ala	AAA Lys	TTC Phe	GTG Val	CAG Gln 320	960
GAT Asp	CGC Arg	TCC Ser	GGT Gly	AGC Ser 325	CAC His	GGG Gly	ATG Met	ACC Thr	CTT Leu 330	AAC Asn	TCA Ser	CTG Leu	GTT Val	TCC Ser 335	GAC Asp	1008
GGT Gly	TGT Cys	GTG Val	ATC Ile 340	TCC Ser	GGT Gly	TCG Ser	GTG Val	GTG Val 345	GTG Val	CAG Gln	TCC Ser	GTT Val	CTG Leu 350	TTC Phe	TCG Ser	1056
CGC Arg	GTT Val	CGC Arg 355	GTG Val	AAT Asn	TCA Ser	TTC Phe	TGC Cys 360	AAC Asn	ATT Ile	GAT Asp	TCC Ser	GCC Ala 365	GTA Val	TTG Leu	TTA Leu	1104
CCG Pro	GAA Glu 370	GTA Val	TGG Trp	GTA Val	GGT Gly	CGC Arg 375	TCG Ser	TGC Cys	CGT Arg	CTG Leu	CGC Arg 380	CGC Arg	TGC Cys	GTC Val	ATC Ile	1152
GAT Asp 385	CGT Arg	GCT Ala	TGT Cys	GTT Val	ATT Ile 390	CCG Pro	GAA Glu	GGC Gly	ATG Met	GTG Val 395	ATT Ile	GGT Gly	GAA Glu	AAC Asn	GCA Ala 400	1200
GAG Glu	GAA Glu	GAT Asp	GCA Ala	CGT Arg 405	CGT Arg	TTC Phe	TAT Tyr	CGT Arg	TCA Ser 410	GAA Glu	GAA Glu	GGC Gly	ATC Ile 415	GTG Val	CTG Leu	1248

81.

GTA ACG CGC GAA ATG CTA CGG AAG TTA GGG CAT AAA CAG GAG
 Val Thr Arg Glu Met Leu Arg Lys Leu Gly His Lys Gln Glu
 420 425 430

TAA

1296

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 431 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

Met Val Ser Leu Glu Lys Asn Asp His Leu Met Leu Ala Arg Gln Leu
 1 5 10 15

Pro Leu Lys Ser Val Ala Leu Ile Leu Ala Gly Gly Arg Gly Thr Arg
 20 25 30

Leu Lys Asp Leu Thr Asn Lys Arg Ala Lys Pro Ala Val His Phe Gly
 35 40 45

Gly Lys Phe Arg Ile Ile Asp Phe Ala Leu Ser Asn Cys Ile Asn Ser
 50 55 60

Gly Ile Arg Arg Met Gly Val Ile Thr Gln Tyr Gln Ser His Thr Leu
 65 70 75 80

Val Gln His Ile Gln Arg Gly Trp Ser Phe Phe Asn Glu Glu Met Asn
 85 90 95

Glu Phe Val Asp Leu Leu Pro Ala Gln Gln Arg Met Lys Gly Glu Asn
 100 105 110

Trp Tyr Arg Gly Thr Ala Asp Ala Val Thr Gln Asn Leu Asp Ile Ile
 115 120 125

Arg Arg Tyr Lys Ala Glu Tyr Val Val Ile Leu Ala Gly Asp His Ile
 130 135 140

Tyr Lys Gln Asp Tyr Ser Arg Met Leu Ile Asp His Val Glu Lys Gly
 145 150 155 160

Val Arg Cys Thr Val Val Cys Met Pro Val Pro Ile Glu Glu Ala Ser
 165 170 175

Ala Phe Gly Val Met Ala Val Asp Glu Asn Asp Lys Thr Ile Glu Phe
 180 185 190

Val Glu Lys Pro Ala Asn Pro Pro Ser Met Pro Asn Asp Pro Ser Lys
 195 200 205

Ser Leu Ala Ser Met Gly Ile Tyr Val Phe Asp Ala Asp Tyr Leu Tyr
 210 215 220

Glu Leu Leu Glu Glu Asp Asp Arg Asp Glu Asn Ser Ser His Asp Phe
 225 230 235 240

Gly Lys Asp Leu Ile Pro Lys Ile Thr Glu Ala Gly Leu Ala Tyr Ala

82

245	250
His Pro Phe Pro Leu Ser Cys Val Gln Ser Asp Pro Asp Ala Glu Pro 260 265 270	
Tyr Trp Arg Asp Val Gly Thr Leu Glu Ala Tyr Trp Lys Ala Asn Leu 275 280 285	
Asp Leu Ala Ser Val Val Pro Glu Leu Asp Met Tyr Asp Arg Asn Trp 290 295 300	
Pro Ile Arg Thr Tyr Asn Glu Ser Leu Pro Pro Ala Lys Phe Val Gln 305 310 315 320	
Asp Arg Ser Gly Ser His Gly Met Thr Leu Asn Ser Leu Val Ser Asp 325 330 335	
Gly Cys Val Ile Ser Gly Ser Val Val Val Gln Ser Val Leu Phe Ser 340 345 350	
Arg Val Arg Val Asn Ser Phe Cys Asn Ile Asp Ser Ala Val Leu Leu 355 360 365	
Pro Glu Val Trp Val Gly Arg Ser Cys Arg Leu Arg Arg Cys Val Ile 370 375 380	
Asp Arg Ala Cys Val Ile Pro Glu Gly Met Val Ile Gly Glu Asn Ala 385 390 395 400	
Glu Glu Asp Ala Arg Arg Phe Tyr Arg Ser Glu Glu Gly Ile Val Leu 405 410 415	
Val Thr Arg Glu Met Leu Arg Lys Leu Gly His Lys Gln Glu Arg 420 425 430	

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 355 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 88..354

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

AAGCTTGTTT TCATTGTTGT TATCATTATA TATAGATGAC CAAAGCACTA GACCAAACCT	60
CAGTCACACA AAGAGTAAAG AAGAACA ATG GCT TCC TCT ATG CTC TCT TCC	111
Met Ala Ser Ser Met Leu Ser Ser	
1 5	
GCT ACT ATG GTT GCC TCT CCG GCT CAG GCC ACT ATG GTC GCT CCT TTC	159
Ala Thr Met Val Ala Ser Pro Ala Gln Ala Thr Met Val Ala Pro Phe	
10 15 20	
AAC GGA CTT AAG TCC TCC GCT GCC TTC CCA GCC ACC CGC AAG GCT AAC	207

83

Asn	Gly	Leu	Lys	Ser	Ser	Ala	Ala	Phe	Pro	Ala	Thr	Arg	Lys			
25					30					35						
AAC	GAC	ATT	ACT	TCC	ATC	ACA	AGC	AAC	GGC	GGA	AGA	GTT	AAC	TGC	ATG	255
Asn	Asp	Ile	Thr	Ser	Ile	Thr	Ser	Asn	Gly	Gly	Arg	Val	Asn	Cys	Met	
				45					50					55		
CAG	GTG	TGG	CCT	CCG	ATT	GGA	AAG	AAG	AAG	TTT	GAG	ACT	CTC	TCT	TAC	303
Gln	Val	Trp	Pro	Pro	Ile	Gly	Lys	Lys	Lys	Phe	Glu	Thr	Leu	Ser	Tyr	
			60					65					70			
CTT	CCT	GAC	CTT	ACC	GAT	TCC	GGT	GGT	CGC	GTC	AAC	TGC	ATG	CAG	GCC	351
Leu	Pro	Asp	Leu	Thr	Asp	Ser	Gly	Gly	Arg	Val	Asn	Cys	Met	Gln	Ala	
		75					80					85				
ATG	G															355
Met																

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 89 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Met 1	Ala	Ser	Ser	Met 5	Leu	Ser	Ser	Ala	Thr 10	Met	Val	Ala	Ser	Pro 15	Ala
Gln	Ala	Thr	Met 20	Val	Ala	Pro	Phe	Asn 25	Gly	Leu	Lys	Ser	Ser 30	Ala	Ala
Phe	Pro	Ala 35	Thr	Arg	Lys	Ala	Asn 40	Asn	Asp	Ile	Thr	Ser 45	Ile	Thr	Ser
Asn	Gly 50	Gly	Arg	Val	Asn	Cys 55	Met	Gln	Val	Trp	Pro 60	Pro	Ile	Gly	Lys
Lys 65	Lys	Phe	Glu	Thr	Leu 70	Ser	Tyr	Leu	Pro	Asp 75	Leu	Thr	Asp	Ser	Gly 80
Gly	Arg	Val	Asn	Cys 85	Met	Gln	Ala	Met							

(2) INFORMATION FOR SEO ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1575 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

(A) NAME/KEY: CDS

(B) LOCATION: 3..1565

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

CC	ATG	GCG	GCT	TCC	ATT	GGA	GCC	TTA	AAA	TCT	TCA	CCT	TCT	TCT	AAC	47
Met	Ala	Ala	Ser	Ile	Gly	Ala	Leu	Lys	Ser	Ser	Pro	Ser	Ser	Ser	Asn	
1				5					10						15	
AAT	TGC	ATC	AAT	GAG	AGA	AGA	AAT	GAT	TCT	ACA	CGT	GCT	GTA	TCC	AGC	95
Asn	Cys	Ile	Asn	Glu	Arg	Arg	Asn	Asp	Ser	Thr	Arg	Ala	Val	Ser	Ser	
				20					25					30		
AGA	AAT	CTC	TCA	TTT	TCG	TCT	TCT	CAT	CTC	GCC	GGA	GAC	AAG	TTG	ATG	143
Arg	Asn	Leu	Ser	Phe	Ser	Ser	Ser	His	Leu	Ala	Gly	Asp	Lys	Leu	Met	
			35					40					45			
CCT	GTA	TCG	TCC	TTA	CGT	TCC	CAA	GGA	GTC	CGA	TTC	AAT	GTG	AGA	AGA	191
Pro	Val	Ser	Ser	Leu	Arg	Ser	Gln	Gly	Val	Arg	Phe	Asn	Val	Arg	Arg	
		50					55					60				
AGT	CCA	ATG	ATT	GTG	TCG	CCA	AAG	GCT	GTT	TCT	GAT	TCG	CAG	AAT	TCA	239
Ser	Pro	Met	Ile	Val	Ser	Pro	Lys	Ala	Val	Ser	Asp	Ser	Gln	Asn	Ser	
	65					70					75					
CAG	ACA	TGT	CTA	GAC	CCA	GAT	GCT	AGC	CGG	AGT	GTT	TTG	GGA	ATT	ATT	287
Gln	Thr	Cys	Leu	Asp	Pro	Asp	Ala	Ser	Arg	Ser	Val	Leu	Gly	Ile	Ile	
	80				85				90						95	
CTT	GGA	GGT	GGA	GCT	GGG	ACC	CGA	CTT	TAT	CCT	CTA	ACT	AAA	AAA	AGA	335
Leu	Gly	Gly	Gly	Ala	Gly	Thr	Arg	Leu	Tyr	Pro	Leu	Thr	Lys	Lys	Arg	
				100					105					110		
GCA	AAG	CCA	GCT	GTT	CCA	CTT	GGA	GCA	AAT	TAT	CGT	CTG	ATT	GAC	ATT	383
Ala	Lys	Pro	Ala	Val	Pro	Leu	Gly	Ala	Asn	Tyr	Arg	Leu	Ile	Asp	Ile	
			115				120						125			
CCT	GTA	AGC	AAC	TGC	TTG	AAC	AGT	AAT	ATA	TCC	AAG	ATT	TAT	GTT	CTC	431
Pro	Val	Ser	Asn	Cys	Leu	Asn	Ser	Asn	Ile	Ser	Lys	Ile	Tyr	Val	Leu	
		130				135						140				
ACA	CAA	TTC	AAC	TCT	GCC	TCT	CTG	AAT	CGC	CAC	CTT	TCA	CGA	GCA	TAT	479
Thr	Gln	Phe	Asn	Ser	Ala	Ser	Leu	Asn	Arg	His	Leu	Ser	Arg	Ala	Tyr	
	145					150					155					
GCT	AGC	AAC	ATG	GGA	GGA	TAC	AAA	AAC	GAG	GGC	TTT	GTG	GAA	GTT	CTT	527
Ala	Ser	Asn	Met	Gly	Gly	Tyr	Lys	Asn	Glu	Gly	Phe	Val	Glu	Val	Leu	
	160			165					170					175		
GCT	GCT	CAA	CAA	AGT	CCA	GAG	AAC	CCC	GAT	TGG	TTC	CAG	GGC	ACG	GCT	575
Ala	Ala	Gln	Gln	Ser	Pro	Glu	Asn	Pro	Asp	Trp	Phe	Gln	Gly	Thr	Ala	
				180					185					190		
GAT	GCT	GTC	AGA	CAA	TAT	CTG	TGG	TTG	TTT	GAG	GAG	CAT	ACT	GTT	CTT	623
Asp	Ala	Val	Arg	Gln	Tyr	Leu	Trp	Leu	Phe	Glu	Glu	His	Thr	Val	Leu	
			195					200					205			
GAA	TAC	CTT	ATA	CTT	GCT	GGA	GAT	CAT	CTG	TAT	CGA	ATG	GAT	TAT	GAA	671
Glu	Tyr	Leu	Ile	Leu	Ala	Gly	Asp	His	Leu	Tyr	Arg	Met	Asp	Tyr	Glu	
		210					215					220				
AAG	TTT	ATT	CAA	GCC	CAC	AGA	GAA	ACA	GAT	GCT	GAT	ATT	ACC	GTT	GCC	719
Lys	Phe	Ile	Gln	Ala	His	Arg	Glu	Thr	Asp	Ala	Asp	Ile	Thr	Val	Ala	
	225					230					235					
GCA	CTG	CCA	ATG	GAC	GAG	AAG	CGT	GCC	ACT	GCA	TTC	GGT	CTC	ATG	AAG	767

85

Ala 240	Leu	Pro	Met	Asp 245	Glu	Lys	Arg	Ala	Thr	Ala 250	Phe	Gly	Leu				
ATT Ile	GAC Asp	GAA Glu	GAA Glu	GGA Gly 260	CGC Arg	ATT Ile	ATT Ile	GAA Glu	TTT Phe 265	GCA Ala	GAG Glu	AAA Lys	CCG Pro	CAA Gln 270	GGA Gly		815
GAG Glu	CAA Gln	TTG Leu	CAA Gln 275	GCA Ala	ATG Met	AAA Lys	GTG Val	GAT Asp 280	ACT Thr	ACC Thr	ATT Ile	TTA Leu	GGT Gly 285	CTT Leu	GAT Asp		863
GAC Asp	AAG Lys	AGA Arg 290	GCT Ala	AAA Lys	GAA Glu	ATG Met	CCT Pro 295	TTC Phe	ATT Ile	GCC Ala	AGT Ser	ATG Met 300	GGT Gly	ATA Ile	TAT Tyr		911
GTC Val 305	ATT Ile	AGC Ser	AAA Lys	GAC Asp	GTG Val	ATG Met 310	TTA Leu	AAC Asn	CTA Leu	CTT Leu	CGT Arg 315	GAC Asp	AAG Lys	TTC Phe	CCT Pro		959
GGG Gly 320	GCC Ala	AAT Asn	GAT Asp	TTT Phe 325	GGT Gly	AGT Ser	GAA Glu	GTT Val	ATT Ile	CCT Pro 330	GGT Gly	GCA Ala	ACT Thr	TCA Ser	CTT Leu 335		1007
GGG Gly	ATG Met	AGA Arg	GTG Val	CAA Gln 340	GCT Ala	TAT Tyr	TTA Leu	TAT Tyr	GAT Asp 345	GGG Gly	TAC Tyr	TGG Trp	GAA Glu	GAT Asp 350	ATT Ile		1055
GGT Gly	ACC Thr	ATT Ile	GAA Glu 355	GCT Ala	TTC Phe	TAC Tyr	AAT Asn	GCC Ala 360	AAT Asn	TTG Leu	GGC Gly	ATT Ile	ACA Thr 365	AAA Lys	AAG Lys		1103
CCG Pro	GTG Val	CCA Pro 370	GAT Asp	TTT Phe	AGC Ser	TTT Phe	TAC Tyr 375	GAC Asp	CGA Arg	TCA Ser	GCC Ala	CCA Pro 380	ATC Ile	TAC Tyr	ACC Thr		1151
CAA Gln 385	CCT Pro	CGA Arg	TAT Tyr	CTA Leu	CCA Pro	CCA Pro	TCA Ser 390	AAA Lys	ATG Met	CTT Leu	GAT Asp 395	GCT Ala	GAT Asp	GTC Val	ACA Thr		1199
GAT Asp 400	AGT Ser	GTC Val	ATT Ile	GGT Gly	GAA Glu 405	GGT Gly	TGT Cys	GTG Val	ATC Ile	AAG Lys 410	AAC Asn	TGT Cys	AAG Lys	ATT Ile	CAT His 415		1247
CAT His	TCC Ser	GTG Val	GTT Val	GGA Gly 420	CTC Leu	AGA Arg	TCA Ser	TGC Cys	ATA Ile 425	TCA Ser	GAG Glu	GGA Gly	GCA Ala	ATT Ile 430	ATA Ile		1295
GAA Glu	GAC Asp	TCA Ser	CTT Leu 435	TTG Leu	ATG Met	GGG Gly	GCA Ala	GAT Asp 440	TAC Tyr	TAT Tyr	GAG Glu	ACT Thr	GAT Asp 445	GCT Ala	GAC Asp		1343
AGG Arg	AAG Lys	TTG Leu 450	CTG Leu	GCT Ala	GCA Ala	AAG Lys	GGC Gly 455	AGT Ser	GTC Val	CCA Pro	ATT Ile	GGC Gly 460	ATC Ile	GGC Gly	AAG Lys		1391
AAT Asn 465	TGT Cys	CAC His	ATT Ile	AAA Lys	AGA Arg	GCC Ala 470	ATT Ile	ATC Ile	GAC Asp	AAG Lys	AAT Asn	GCC Ala	CGT Arg	ATA Ile	GGG Gly		1439
GAC Asp 480	AAT Asn	GTG Val	AAG Lys	ATC Ile	ATT Ile	AAC Asn	AAA Lys	GAC Asp	AAC Asn	GTT Val 490	CAA Gln	GAA Glu	GCG Ala	GCT Ala	AGG Arg 495		1487
GAA	ACA	GAT	GGA	TAC	TTC	ATC	AAG	AGT	GGG	ATT	GTC	ACC	GTC	ATC	AAG		1535

86

Glu Thr Asp Gly Tyr Phe Ile Lys Ser Gly Ile Val Thr Val 1
500 505 5

GAT GCT TTG ATT CCA AGT GGA ATC ATC ATC TGATGAGCTC
Asp Ala Leu Ile Pro Ser Gly Ile Ile Ile
515 520

1575

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 521 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

Met 1	Ala	Ala	Ser	Ile 5	Gly	Ala	Leu	Lys	Ser 10	Ser	Pro	Ser	Ser	Asn 15	Asn
Cys	Ile	Asn	Glu 20	Arg	Arg	Asn	Asp	Ser 25	Thr	Arg	Ala	Val	Ser 30	Ser	Arg
Asn	Leu	Ser 35	Phe	Ser	Ser	Ser	His 40	Leu	Ala	Gly	Asp	Lys 45	Leu	Met	Pro
Val	Ser 50	Ser	Leu	Arg	Ser	Gln 55	Gly	Val	Arg	Phe	Asn 60	Val	Arg	Arg	Ser
Pro 65	Met	Ile	Val	Ser	Pro 70	Lys	Ala	Val	Ser	Asp 75	Ser	Gln	Asn	Ser	Gln 80
Thr	Cys	Leu	Asp	Pro 85	Asp	Ala	Ser	Arg	Ser 90	Val	Leu	Gly	Ile	Ile 95	Leu
Gly	Gly	Gly	Ala 100	Gly	Thr	Arg	Leu	Tyr 105	Pro	Leu	Thr	Lys	Lys 110	Arg	Ala
Lys	Pro	Ala 115	Val	Pro	Leu	Gly	Ala 120	Asn	Tyr	Arg	Leu	Ile 125	Asp	Ile	Pro
Val	Ser 130	Asn	Cys	Leu	Asn	Ser 135	Asn	Ile	Ser	Lys	Ile 140	Tyr	Val	Leu	Thr
Gln 145	Phe	Asn	Ser	Ala	Ser 150	Leu	Asn	Arg	His	Leu 155	Ser	Arg	Ala	Tyr	Ala 160
Ser	Asn	Met	Gly	Gly 165	Tyr	Lys	Asn	Glu	Gly 170	Phe	Val	Glu	Val	Leu 175	Ala
Ala	Gln	Gln	Ser 180	Pro	Glu	Asn	Pro	Asp 185	Trp	Phe	Gln	Gly	Thr 190	Ala	Asp
Ala	Val	Arg 195	Gln	Tyr	Leu	Trp	Leu 200	Phe	Glu	Glu	His	Thr 205	Val	Leu	Glu
Tyr	Leu 210	Ile	Leu	Ala	Gly	Asp 215	His	Leu	Tyr	Arg	Met 220	Asp	Tyr	Glu	Lys
Phe 225	Ile	Gln	Ala	His	Arg 230	Glu	Thr	Asp	Ala	Asp 235	Ile	Thr	Val	Ala	Ala 240

87

Leu Pro Met Asp Glu Lys Arg Ala Thr Ala Phe Gly Leu Met Lys
 245 250 25
 Asp Glu Glu Gly Arg Ile Ile Glu Phe Ala Glu Lys Pro Gln Gly Glu
 260 265 270
 Gln Leu Gln Ala Met Lys Val Asp Thr Thr Ile Leu Gly Leu Asp Asp
 275 280 285
 Lys Arg Ala Lys Glu Met Pro Phe Ile Ala Ser Met Gly Ile Tyr Val
 290 295 300
 Ile Ser Lys Asp Val Met Leu Asn Leu Leu Arg Asp Lys Phe Pro Gly
 305 310 315 320
 Ala Asn Asp Phe Gly Ser Glu Val Ile Pro Gly Ala Thr Ser Leu Gly
 325 330 335
 Met Arg Val Gln Ala Tyr Leu Tyr Asp Gly Tyr Trp Glu Asp Ile Gly
 340 345 350
 Thr Ile Glu Ala Phe Tyr Asn Ala Asn Leu Gly Ile Thr Lys Lys Pro
 355 360 365
 Val Pro Asp Phe Ser Phe Tyr Asp Arg Ser Ala Pro Ile Tyr Thr Gln
 370 375 380
 Pro Arg Tyr Leu Pro Pro Ser Lys Met Leu Asp Ala Asp Val Thr Asp
 385 390 395 400
 Ser Val Ile Gly Glu Gly Cys Val Ile Lys Asn Cys Lys Ile His His
 405 410 415
 Ser Val Val Gly Leu Arg Ser Cys Ile Ser Glu Gly Ala Ile Ile Glu
 420 425 430
 Asp Ser Leu Leu Met Gly Ala Asp Tyr Tyr Glu Thr Asp Ala Asp Arg
 435 440 445
 Lys Leu Leu Ala Ala Lys Gly Ser Val Pro Ile Gly Ile Gly Lys Asn
 450 455 460
 Cys His Ile Lys Arg Ala Ile Ile Asp Lys Asn Ala Arg Ile Gly Asp
 465 470 475 480
 Asn Val Lys Ile Ile Asn Lys Asp Asn Val Gln Glu Ala Ala Arg Glu
 485 490 495
 Thr Asp Gly Tyr Phe Ile Lys Ser Gly Ile Val Thr Val Ile Lys Asp
 500 505 510
 Ala Leu Ile Pro Ser Gly Ile Ile Ile
 515 520

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1519 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

88

(ix) FEATURE:

(A) NAME/KEY: CDS

(B) LOCATION: 1..1410

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

AAC AAG ATC AAA CCT GGG GTT GCT TAC TCT GTG ATC ACT ACT GAA AAT	48
Asn Lys Ile Lys Pro Gly Val Ala Tyr Ser Val Ile Thr Thr Glu Asn	
1 5 10 15	
GAC ACA CAG ACT GTG TTC GTA GAT ATG CCA CGT CTT GAG AGA CGC CGG	96
Asp Thr Gln Thr Val Phe Val Asp Met Pro Arg Leu Glu Arg Arg Arg	
20 25 30	
GCA AAT CCA AAG GAT GTG GCT GCA GTC ATA CTG GGA GGA GGA GAA GGG	144
Ala Asn Pro Lys Asp Val Ala Ala Val Ile Leu Gly Gly Gly Glu Gly	
35 40 45	
ACC AAG TTA TTC CCA CTT ACA AGT AGA ACT GCA ACC CCT GCT GTT CCG	192
Thr Lys Leu Phe Pro Leu Thr Ser Arg Thr Ala Thr Pro Ala Val Pro	
50 55 60	
GTT GGA GGA TGC TAC AGG CTA ATA GAC ATC CCA ATG AGC AAC TGT ATC	240
Val Gly Gly Cys Tyr Arg Leu Ile Asp Ile Pro Met Ser Asn Cys Ile	
65 70 75 80	
AAC AGT GCT ATT AAC AAG ATT TTT GTG CTG ACA CAG TAC AAT TCT GCT	288
Asn Ser Ala Ile Asn Lys Ile Phe Val Leu Thr Gln Tyr Asn Ser Ala	
85 90 95	
CCC CTG AAT CGT CAC ATT GCT CGA ACA TAT TTT GGC AAT GGT GTG AGC	336
Pro Leu Asn Arg His Ile Ala Arg Thr Tyr Phe Gly Asn Gly Val Ser	
100 105 110	
TTT GGA GAT GGA TTT GTC GAG GTA CTA GCT GCA ACT CAG ACA CCC GGG	384
Phe Gly Asp Gly Phe Val Glu Val Leu Ala Ala Thr Gln Thr Pro Gly	
115 120 125	
GAA GCA GGA AAA AAA TGG TTT CAA GGA ACA GCA GAT GCT GTT AGA AAA	432
Glu Ala Gly Lys Lys Trp Phe Gln Gly Thr Ala Asp Ala Val Arg Lys	
130 135 140	
TTT ATA TGG GTT TTT GAG GAC GCT AAG AAC AAG AAT ATT GAA AAT ATC	480
Phe Ile Trp Val Phe Glu Asp Ala Lys Asn Lys Asn Ile Glu Asn Ile	
145 150 155 160	
GTT GTA CTA TCT GGG GAT CAT CTT TAT AGG ATG GAT TAT ATG GAG TTG	528
Val Val Leu Ser Gly Asp His Leu Tyr Arg Met Asp Tyr Met Glu Leu	
165 170 175	
GTG CAG AAC CAT ATT GAC AGG AAT GCT GAT ATT ACT CTT TCA TGT GCA	576
Val Gln Asn His Ile Asp Arg Asn Ala Asp Ile Thr Leu Ser Cys Ala	
180 185 190	
CCA GCT GAG GAC AGC CGA GCA TCA GAT TTT GGG CTG GTC AAG ATT GAC	624
Pro Ala Glu Asp Ser Arg Ala Ser Asp Phe Gly Leu Val Lys Ile Asp	
195 200 205	
AGC AGA GGC AGA GTA GTC CAG TTT GCT GAA AAA CCA AAA GGT TTT GAT	672
Ser Arg Gly Arg Val Val Gln Phe Ala Glu Lys Pro Lys Gly Phe Asp	
210 215 220	

CTT Leu 225	AAA Lys	GCA Ala	ATG Met	CAA Gln	GTA Val 230	GAT Asp	ACT Thr	ACT Thr	CTT Leu	GTT Val 235	GGA Gly	TTA Leu	TCT Ser	CTC Phe	240	
GAT Asp	GCG Ala	AAG Lys	AAA Lys	TCC Ser 245	CCC Pro	TAT Tyr	ATT Ile	GCT Ala	TCA Ser 250	ATG Met	GGA Gly	GTT Val	TAT Tyr	GTA Val 255	TTC Phe	768
AAG Lys	ACA Thr	GAT Asp	GTA Val 260	TTG Leu	TTG Leu	AAG Lys	CTC Leu	TTG Leu 265	AAA Lys	TGG Trp	AGC Ser	TAT Tyr	CCC Pro 270	ACT Thr	TCT Ser	816
AAT Asn	GAT Asp	TTT Phe 275	GGC Gly	TCT Ser	GAA Glu	ATT Ile	ATA Ile 280	CCA Pro	GCA Ala	GCT Ala	ATT Ile	GAC Asp 285	GAT Asp	TAC Tyr	AAT Asn	864
GTC Val	CAA Gln 290	GCA Ala	TAC Tyr	ATT Ile	TTC Phe	AAA Lys 295	GAC Asp	TAT Tyr	TGG Trp	GAA Glu	GAC Asp 300	ATT Ile	GGA Gly	ACA Thr	ATT Ile	912
AAA Lys 305	TCG Ser	TTT Phe	TAT Tyr	AAT Asn	GCT Ala 310	AGC Ser	TTG Leu	GCA Ala	CTC Leu	ACA Thr 315	CAA Gln	GAG Glu	TTT Phe	CCA Pro	GAG Glu 320	960
TTC Phe	CAA Gln	TTT Phe	TAC Tyr	GAT Asp 325	CCA Pro	AAA Lys	ACA Thr	CCT Pro	TTT Phe 330	TAC Tyr	ACA Thr	TCT Ser	CCT Pro	AGG Arg 335	TTC Phe	1008
CTT Leu	CCA Pro	CCA Pro	ACC Thr 340	AAG Lys	ATA Ile	GAC Asp	AAT Asn	TGC Cys 345	AAG Lys	ATT Ile	AAG Lys	GAT Asp	GCC Ala 350	ATA Ile	ATC Ile	1056
TCT Ser	CAT His	GGA Gly 355	TGT Cys	TTC Phe	TTG Leu	CGA Arg	GAT Asp 360	TGT Cys	TCT Ser	GTG Val	GAA Glu	CAC His 365	TCC Ser	ATA Ile	GTG Val	1104
GGT Gly	GAA Glu 370	AGA Arg	TCG Ser	CGC Arg	TTA Leu	GAT Asp 375	TGT Cys	GGT Gly	GTT Val	GAA Glu	CTG Leu 380	AAG Lys	GAT Asp	ACT Thr	TTC Phe	1152
ATG Met 385	ATG Met	GGA Gly	GCA Ala	GAC Asp	TAC Tyr 390	TAC Tyr	CAA Gln	ACA Thr	GAA Glu	TCT Ser 395	GAG Glu	ATT Ile	GCC Ala	TCC Ser	CTG Leu 400	1200
TTA Leu	GCA Ala	GAG Glu	GGG Gly	AAA Lys 405	GTA Val	CCG Pro	ATT Ile	GGA Gly	ATT Ile 410	GGG Gly	GAA Glu	AAT Asn	ACA Thr	AAA Lys 415	ATA Ile	1248
AGG Arg	AAA Lys	TGT Cys	ATC Ile 420	ATT Ile	GAC Asp	AAG Lys	AAC Asn	GCA Ala 425	AAG Lys	ATA Ile	GGA Gly	AAG Lys	AAT Asn 430	GTT Val	TCA Ser	1296
ATC Ile	ATA Ile	AAT Asn 435	AAA Lys	GAC Asp	GGT Gly	GTT Val	CAA Gln 440	GAG Glu	GCA Ala	GAC Asp	CGA Arg	CCA Pro	GAG Glu	GAA Glu	GGA Gly	1344
TTC Phe	Tyr 450	ATA Ile	CGA Arg	TCA Ser	GGG Gly	ATA Ile 455	ATC Ile	ATT Ile	ATA Ile	TTA Leu	GAG Glu 460	AAA Lys	GCC Ala	ACA Thr	ATT Ile	1392
AGA Arg 465	GAT Asp	GGA Gly	ACA Thr	GTC Val	ATC Ile 470	TGA	ACT	AGG	AGG	CAC	CCT	TCT	TGTT	GAACTA		1440

90

CTGGAGATCC AAATCTCAAC TTGAAGAAGG TCAAGGGTGA TCCTAGCAC -
 GACTCCCCGA AGGAAGCTT

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 470 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

Asn	Lys	Ile	Lys	Pro	Gly	Val	Ala	Tyr	Ser	Val	Ile	Thr	Thr	Glu	Asn	1	5	10	15
Asp	Thr	Gln	Thr	Val	Phe	Val	Asp	Met	Pro	Arg	Leu	Glu	Arg	Arg	Arg	20	25	30	
Ala	Asn	Pro	Lys	Asp	Val	Ala	Ala	Val	Ile	Leu	Gly	Gly	Gly	Glu	Gly	35	40	45	
Thr	Lys	Leu	Phe	Pro	Leu	Thr	Ser	Arg	Thr	Ala	Thr	Pro	Ala	Val	Pro	50	55	60	
Val	Gly	Gly	Cys	Tyr	Arg	Leu	Ile	Asp	Ile	Pro	Met	Ser	Asn	Cys	Ile	65	70	75	80
Asn	Ser	Ala	Ile	Asn	Lys	Ile	Phe	Val	Leu	Thr	Gln	Tyr	Asn	Ser	Ala	85	90	95	
Pro	Leu	Asn	Arg	His	Ile	Ala	Arg	Thr	Tyr	Phe	Gly	Asn	Gly	Val	Ser	100	105	110	
Phe	Gly	Asp	Gly	Phe	Val	Glu	Val	Leu	Ala	Ala	Thr	Gln	Thr	Pro	Gly	115	120	125	
Glu	Ala	Gly	Lys	Lys	Trp	Phe	Gln	Gly	Thr	Ala	Asp	Ala	Val	Arg	Lys	130	135	140	
Phe	Ile	Trp	Val	Phe	Glu	Asp	Ala	Lys	Asn	Lys	Asn	Ile	Glu	Asn	Ile	145	150	155	160
Val	Val	Leu	Ser	Gly	Asp	His	Leu	Tyr	Arg	Met	Asp	Tyr	Met	Glu	Leu	165	170	175	
Val	Gln	Asn	His	Ile	Asp	Arg	Asn	Ala	Asp	Ile	Thr	Leu	Ser	Cys	Ala	180	185	190	
Pro	Ala	Glu	Asp	Ser	Arg	Ala	Ser	Asp	Phe	Gly	Leu	Val	Lys	Ile	Asp	195	200	205	
Ser	Arg	Gly	Arg	Val	Val	Gln	Phe	Ala	Glu	Lys	Pro	Lys	Gly	Phe	Asp	210	215	220	
Leu	Lys	Ala	Met	Gln	Val	Asp	Thr	Thr	Leu	Val	Gly	Leu	Ser	Pro	Gln	225	230	235	240
Asp	Ala	Lys	Lys	Ser	Pro	Tyr	Ile	Ala	Ser	Met	Gly	Val	Tyr	Val	Phe	245	250	255	

91

Lys Thr Asp Val Leu Leu Lys Leu Leu Lys Trp Ser Tyr Pro ?
 260 265 270
 Asn Asp Phe Gly Ser Glu Ile Ile Pro Ala Ala Ile Asp Asp Tyr Asn
 275 280 285
 Val Gln Ala Tyr Ile Phe Lys Asp Tyr Trp Glu Asp Ile Gly Thr Ile
 290 295 300
 Lys Ser Phe Tyr Asn Ala Ser Leu Ala Leu Thr Gln Glu Phe Pro Glu
 305 310 315 320
 Phe Gln Phe Tyr Asp Pro Lys Thr Pro Phe Tyr Thr Ser Pro Arg Phe
 325 330 335
 Leu Pro Pro Thr Lys Ile Asp Asn Cys Lys Ile Lys Asp Ala Ile Ile
 340 345 350
 Ser His Gly Cys Phe Leu Arg Asp Cys Ser Val Glu His Ser Ile Val
 355 360 365
 Gly Glu Arg Ser Arg Leu Asp Cys Gly Val Glu Leu Lys Asp Thr Phe
 370 375 380
 Met Met Gly Ala Asp Tyr Tyr Gln Thr Glu Ser Glu Ile Ala Ser Leu
 385 390 395 400
 Leu Ala Glu Gly Lys Val Pro Ile Gly Ile Gly Glu Asn Thr Lys Ile
 405 410 415
 Arg Lys Cys Ile Ile Asp Lys Asn Ala Lys Ile Gly Lys Asn Val Ser
 420 425 430
 Ile Ile Asn Lys Asp Gly Val Gln Glu Ala Asp Arg Pro Glu Glu Gly
 435 440 445
 Phe Tyr Ile Arg Ser Gly Ile Ile Ile Ile Leu Glu Lys Ala Thr Ile
 450 455 460
 Arg Asp Gly Thr Val Ile
 465 470

(2) INFORMATION FOR SEQ ID NO:11:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 35 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

GTTGATAACA AGATCTGTTA ACCATGGCGG CTTCC

35

(2) INFORMATION FOR SEQ ID NO:12:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 33 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

CCAGTTAAAA CGGAGCTCAT CAGATGATGA TTC

33

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 30 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

GTGTGAGAAC ATAAATCTTG GATATGTTAC

30

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 28 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

GAATTCACAG GGCCATGGCT CTAGACCC

28

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 40 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

AAGATCAAAC CTGCCATGGC TTACTCTGTG ATCACTACTG

40

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 39 base pairs -

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

GGGAATTCAA GCTTGGATCC CGGGCCCCCC CCCCCCCC

39

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 24 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

GGGAATTCAA GCTTGGATCC CGGG

24

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 32 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

CCTCTAGACA GTCGATCAGG AGCAGATGTA CG

32

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 25 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

GGAGTTAGCC ATGGTTAGTT TAGAG

25

(2) INFORMATION FOR SEQ ID NO:20:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 34 base pairs -
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single

94

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

GGCCGAGCTC GTCAACGCCG TCTGCGATTT GTGC

34

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 19 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

GATTTAGGTG AACTATAG

19

(2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 42 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

AGAGAGATCT AGAACAATGG CTCCTCTAT GCTCTCTTCC GC

42

(2) INFORMATION FOR SEQ ID NO:23:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 39 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (synthetic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

GGCCGAGCTC TAGATTATCG CTCCTGTTTA TGCCCTAAC

39

Claims:

1. A method for increasing the starch content of a plant which comprises altering said plant to increase the ADPglucose pyrophosphorylase activity in said plant.

2. A method of producing genetically transformed plants which have elevated starch content, comprising the steps of:

- (a) inserting into the genome of a plant cell a recombinant, double-stranded DNA molecule comprising
 - (i) a promoter which functions in plants to cause the production of an RNA sequence in the target plant tissues,
 - (ii) a structural DNA sequence that causes the production of an RNA sequence which encodes a fusion polypeptide comprising an amino-terminal plastid transit peptide and an ADPglucose pyrophosphorylase enzyme,
 - (iii) a 3' non-translated DNA sequence which functions in plant cells to cause transcriptional termination and the addition of polyadenylated nucleotides to the 3' end of the RNA sequence;
- (b) obtaining transformed plant cells; and

(c) regenerating from the transformed plant cells genetically transformed plants which have an elevated starch content.

5 3. A method of claim 2 in which the ADPglucose pyrophosphorylase enzyme is deregulated.

 4. A method of claim 3 in which the ADPglucose pyrophosphorylase enzyme is from bacteria.

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 5. A method of claim 3 in which the ADPglucose pyrophosphorylase enzyme is from plants or algae.

 6. A recombinant, double-stranded DNA molecule
15 comprising in sequence:

- (a) a promoter which functions in plants to cause the production of an RNA sequence in the target plant tissues;
- (b) a structural DNA sequence that causes the
20 production of an RNA sequence which encodes a fusion polypeptide comprising an amino-terminal plastid transit peptide and an ADPglucose pyrophosphorylase enzyme; and
- (c) a 3' non-translated region which functions
25 in plant cells to cause transcriptional termination and the addition of polyadenylated nucleotides to the 3' end of the RNA sequence,

30 said promoter is heterologous with respect to said structural DNA.

7. A DNA molecule of claim 6 in which the ADPglucose pyrophosphorylase enzyme is deregulated.

5 8. A DNA molecule of claim 6 in which the plastid transit peptide is heterologous to the source of the ADPglucose pyrophosphorylase structural DNA.

10 9. A DNA molecule of claim 8 in which the ADPglucose pyrophosphorylase is from bacteria.

10. A plant cell comprising a recombinant, double-stranded DNA molecule comprising in sequence:

- 15 (a) a promoter which functions in plants to cause the production of an RNA sequence in target plant tissues;
- 20 (b) a structural DNA sequence that causes the production of an RNA sequence which encodes a fusion polypeptide comprising an amino-terminal plastid transit peptide and an ADPglucose pyrophosphorylase enzyme; and
- 25 (c) a 3' non-translated region which functions in plant cells to cause transcriptional termination and the addition of polyadenylated nucleotides to the 3' end of the RNA sequence

in which the DNA molecule is foreign to said plant cell.

30 11. A plant cell of claim 11 in which the ADPglucose pyrophosphorylase enzyme is deregulated.

12. A plant cell of claim 11 in which the promoter is heterologous with respect to the ADPglucose pyrophosphorylase structural DNA.

5 13. A plant cell of claim 12 in which the plastid transit peptide is heterologous to the source of the ADPglucose pyrophosphorylase structural DNA.

10 14. A plant cell of claim 13 in which the ADPglucose pyrophosphorylase is from bacteria.

15 15. A plant cell of claim 10 selected from the group consisting of corn, wheat, rice, carrot, onion, pea, tomato, potato and sweet potato, peanut, canola/oilseed rape, barley, sorghum, cassava, banana, soybeans, lettuce, apple and walnut.

16. A plant consisting of plant cells of claim 10.

20 17. A plant of claim 16 in which the ADPglucose pyrophosphorylase enzyme is deregulated.

25 18. A plant of claim 17 in which the promoter is heterologous to the source of the ADPglucose pyrophosphorylase structural DNA.

19. A plant of claim 17 in which the plastid transit peptide is heterologous to the source of the ADPglucose pyrophosphorylase structural DNA.

30 20. A plant of claim 18 in which the ADPglucose pyrophosphorylase is from bacteria.

21. A potato plant cell of claim 10.
22. A potato plant cell of claim 14.
- 5 23. A potato plant of claim 18.
24. A potato plant of claim 20.
- 10 25. A potato plant of claim 22 which is var. Russet-Burbank.
26. A potato plant of claim 24 which is var. Russet-Burbank.
- 15 27. A method of claim 1 in which said plant is potato.
28. A method of claim 2 in which said plant is potato.
29. A method of claim 3 in which said plant is potato.
- 20 30. A method of claim 4 in which said plant is potato.
31. A tomato plant cell of claim 10.
- 25 32. A tomato plant cell of claim 14.
33. A tomato plant of claim 16.
34. A tomato plant of claim 20.
- 30 35. A method of claim 1 in which said plant is tomato.

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36. A method of claim 2 in which said plant is
tomato.

5 37. A method of claim 3 in which said plant is
tomato.

38. A method of claim 4 in which said plant is
tomato.

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DNA ATGGTTAGTTTAGAGAAGAACGATCACTTAATGTTGGCGGCCAGCTGCCATTGAAATCT
1 -----|-----|-----|-----|-----|-----|
Protein M V S L E K N D H L M L A R Q L P L K S

GTTGCCCTGATACTGGCGGGAGGACGTGGTACCCGCCTGAAGGATTTAACCAATAAGCGA
61 -----|-----|-----|-----|-----|-----|
V A L I L A G G R G T R L K D L T N K R

GCAAAACCGGCCGTACACTTCGGCGGTAAGTTCCGCATTATCGACTTTGCGCTGTCTAAC
121 -----|-----|-----|-----|-----|-----|
A K P A V H F G G K F R I I D F A L S N

TGCATCAACTCCGGGATCCGTCGTATGGGCGTGATCAGCCAGTACCAGTCCCACACTCTG
181 -----|-----|-----|-----|-----|-----|
C I N S G I R R M G V I T Q Y Q S H T L

GTGCAGCACATTCAGCGCGGCTGGTCATTCTTCAATGAAGAAATGAACGAGTTTGTGCGAT
241 -----|-----|-----|-----|-----|-----|
V Q H I Q R G W S F F N E E M N E F V D

CTGCTGCCAGCACAGCAGAGAATGAAAGGGGAAAACCTGGTATCGCGGCACCGCAGATGCG
301 -----|-----|-----|-----|-----|-----|
L L P A Q Q R M K G E N W Y R G T A D A

GTCACCCAAAACCTCGACATTATCCGTCGTTATAAAGCGGAATACGTGGTGATCCTGGCG
361 -----|-----|-----|-----|-----|-----|
V T Q N L D I I R R Y K A E Y V V I L A

GGCGACCATATCTACAAGCAAGACTACTCGCGTATGCTTATCGATCACGTGAAAAAGGT
421 -----|-----|-----|-----|-----|-----|
G D H I Y K Q D Y S R M L I D H V E K G

GTACGTTGTACCGTTGTTTGTATGCCAGTACCGATTGAAGAAGCCTCCGCATTTGGCGTT
481 -----|-----|-----|-----|-----|-----|
V R C T V V C M P V P I E E A S A F G V

ATGGCGGTTGATGAGAACGATAAACTATCGAATTCGTGGAAAAACCTGCTAACCCGCCG
541 -----|-----|-----|-----|-----|-----|
M A V D E N D K T I E F V E K P A N P P

TCAATGCCGAACGATCCGAGCAAATCTCTGGCGAGTATGGGTATCTACGTCTTTGACGCC
601 -----|-----|-----|-----|-----|-----|
S M P N D P S K S L A S M G I Y V F D A

GACTATCTGTATGAACTGCTGGAGAAGACGATCGCGATGAGAACTCCAGCCACGACTTT
661 -----|-----|-----|-----|-----|-----|
D Y L Y E L L E E D D R D E N S S H D F

FIG. 1A

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721 GGCAAAGATTTGATTCCCAAGATCACCGAAGCCGGTCTGGCCTATGCGCACCCGTTCCCG
-----|-----|-----|-----|-----|-----|
G K D L I P K I T E A G L A Y A H P F P

781 CTCTCTTGGCTACAATCCGACCCGGATGCCGAGCCGTA CTGGCGCGATGTGGGTACGCTG
-----|-----|-----|-----|-----|-----|
L S C V Q S D P D A E P Y W R D V G T L

841 GAAGCTTACTGGAAGCGAACCTCGATCTGGCCTCTGTGGTGCCGAACTGGATATGTAC
-----|-----|-----|-----|-----|-----|
E A Y W K A N L D L A S V V P K L D M Y

901 GATCGCAATTGGCCAATTCGCACCTACAATGAATCATTACCGCCAGCGAAATTCGTGCAG
-----|-----|-----|-----|-----|-----|
D R N W P I R T Y N E S L P P A K F V Q

961 GATCGCTCCGGTAGCCACGGGATGACCCTTAACTCACTGGTTTCCGGCGGTTGTGTGATC
-----|-----|-----|-----|-----|-----|
D R S G S H G M T L N S L V S G G C V I

1021 TCCGGTTCGGTGGTGGTGCAGTCCGTTCTGTTCTCGCGCGTTCCGCGTGAATTCATTCTGC
-----|-----|-----|-----|-----|-----|
S G S V V V Q S V L F S R V R V N S F C

1081 AACATTGATTCCGCCGTATTGTTACCGGAAGTATGGGTAGGTGCTCGTGCCTCTGCGC
-----|-----|-----|-----|-----|-----|
N I D S A V L L P E V W V G R S C R L R

1141 CGCTGCGTCATCGATCGTGCTTGTGTTATTCCGGAAGGCATGGTGATTGGTGAAAACGCA
-----|-----|-----|-----|-----|-----|
R C V I D R A C V I P E G M V I G E N A

1201 GAGGAAGATGCACGTCGTTTCTATCGTTCAGAAGAAGGCATCGTGCTGGTAACGCGCGAA
-----|-----|-----|-----|-----|-----|
E E D A R R F Y R S E E G I V L V T R E

1261 ATGCTACGGAAGTTAGGGCATAAACAGGAGCGATAA
-----|-----|-----|-----|
M L R K L G H K Q E R *

FIG. 1B

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DNA ATGGTTAGTTTAGAGAAGAACGATCACTTAATGTTGGCGCGCCAGCTGCCATTGAAATCT
1 -----|-----|-----|-----|-----|-----|
Protein M V S L E K N D H L M L A R Q L P L K S

GTTGCCCTGATACTGGCGGGAGGACGTGGTACCCGCCCTGAAGGATTTAACCAATAAGCGA
61 -----|-----|-----|-----|-----|-----|
V A L I L A G G R G T R L K D L T N K R

GCAAAACCGGCCGTACACTTCGGCGGTAAGTTCCGCATTATCGACTTTGCGCTGTCTAAC
121 -----|-----|-----|-----|-----|-----|
A K P A V H F G G K F R I I D F A L S N

TGCATCAACTCCGGGATCCGTCGTATGGGCGTGATCACCCAGTACCAGTCCACACTCTG
181 -----|-----|-----|-----|-----|-----|
C I N S G I R R M G V I T Q Y Q S H T L

GTGCAGCACATTCAGCGCGGCTGGTCATTCTTCAATGAAGAAATGAACGAGTTTGTGCGAT
241 -----|-----|-----|-----|-----|-----|
V Q H I Q R G W S F F N E E M N E F V D

CTGCTGCCAGCACAGCAGAGAATGAAAGGGGAAAACCTGGTATCGCGGCACCGCAGATGCG
301 -----|-----|-----|-----|-----|-----|
L L P A Q Q R M K G E N W Y R G T A D A

GTCACCCAAAACCTCGACATTATCCGTCGTTATAAAGCGGAATACGTGGTGATCCTGGCG
361 -----|-----|-----|-----|-----|-----|
V T Q N L D I I R R Y K A E Y V V I L A

GGCGACCATATCTACAAGCAAGACTACTCGCGTATGCTTATCGATCACGTGAAAAAGGT
421 -----|-----|-----|-----|-----|-----|
G D H I Y K Q D Y S R M L I D H V E K G

GTACGTTGTACCGTTGTTTGTATGCCAGTACCGATTGAAGAAGCCTCCGCATTGCGGTT
481 -----|-----|-----|-----|-----|-----|
V R C T V V C M P V P I E E A S A F G V

ATGGCGGTTGATGAGAACGATAAACTATCGAATTCGTGGAAAAACCTGCTAACCCGCCG
541 -----|-----|-----|-----|-----|-----|
M A V D E N D K T I E F V E K P A N P P

TCAATGCCGAACGATCCGAGCAAATCTCTGGCGAGTATGGGTATCTACGTCTTTGACGCC
601 -----|-----|-----|-----|-----|-----|
S M P N D P S K S L A S M G I Y V F D A

GACTATCTGTATGAACTGCTGGAAGAAGACGATCGCGATGAGAACTCCAGCCACGACTTT
661 -----|-----|-----|-----|-----|-----|
D Y L Y E L L E E D D R D E N S S H D F

GGCAAAGATTTGATTCCAAGATCACCGAAGCCGGTCTGGCCTATGCGCACCCGTTCCCG
721 -----|-----|-----|-----|-----|-----|
G K D L I P K I T E A G L A Y A H P F P

FIG.2A

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CTCTCTTGCGTACAATCCGACCCGGATGCCGAGCCGTA CTGGCGGATGTGGGTACGCTG
781 -----|-----|-----|-----|-----|-----|
L S C V Q S D P D A E P Y W R D V G T L

GAAGCTTACTGGAAAGCGAACCTCGATCTGGCCTCTGTGGTGCCGGA ACTGGATATGTAC
841 -----|-----|-----|-----|-----|-----|
E A Y W K A N L D L A S V V P E L D M Y

GATCGCAATTGGCCAATTGCGACCTACAATGAATCATTACCGCCAGCGAAATTCGTGCAG
901 -----|-----|-----|-----|-----|-----|
D R N W P I R T Y N E S L P P A K F V Q

GATCGCTCCGGTAGCCACGGGATGACCCTTAACTCACTGGTTTCCGACGGTTGTGTGATC
961 -----|-----|-----|-----|-----|-----|
D R S G S H G M T L N S L V S D G C V I

TCCGGTTCGGTGGTGGTGCAGTCCGTTCTGTTCTCGCGCGTTTCGCGTGAATTCATTCTGC
1021 -----|-----|-----|-----|-----|-----|
S G S V V V Q S V L F S R V R V N S F C

AACATTGATTCCGCCGTATTGTTACCGGAAGTATGGGTAGGTCGCTCGTGCCGTCTGCGC
1081 -----|-----|-----|-----|-----|-----|
N I D S A V L L P E V W V G R S C R L R

CGCTGCGTCATCGATCGTGCTTGTGTTATTCCGGAAGGCATGGTGATTGGTGAAAACGCA
1141 -----|-----|-----|-----|-----|-----|
R C V I D R A C V I P E G M V I G E N A

GAGGAAGATGCACGTCGTTTCTATCGTT CAGAAGAAGGCATCGTGCTGGTAACGCGCGAA
1201 -----|-----|-----|-----|-----|-----|
E E D A R R F Y R S E E G I V L V T R E

ATGCTACGGAAGTTAGGGCATAAACAGGAGCGATAA
1261 -----|-----|-----|-----|-----|
M L R K L G H K Q E R *

FIG. 2B

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H
 i
 n
 d
 I
 I
 I
 aagcttgttctcattgttgttatcattatatatagatgaccaaagcactagaccaaacct
 1 -----|-----|-----|-----|-----|-----| 60
 cagtcacacaaagagtaaagaagaacaatggcttcctctatgctctcttccgctactatg
 61 -----|-----|-----|-----|-----|-----| 120
 M A S S M L S S A T M
 gttgcctctccggctcaggccactatggtcgctcctttcaacggacttaagtcctccgct
 121 -----|-----|-----|-----|-----|-----| 180
 V A S P A Q A T M V A P F N G L K S S A
 gccttcccagccacccgcaaggctaacaacgacattacttccatcacaaagcaacggcgga
 181 -----|-----|-----|-----|-----|-----| 240
 A F P A T R K A N N D I T S I T S N G G
 agagttaactgcatgcagggtgtggcctccgattggaaagaagaagtttgagactctctct
 241 -----|-----|-----|-----|-----|-----| 300
 R V N C M Q V W P P I G K K K F E T L S
 N
 C
 O
 I
 taccttcctgaccttaccgattccggtggtcgctcaactgcatgcaggccatgg
 301 -----|-----|-----|-----|-----|-----| 355
 Y L P D L T D S G G R V N C M Q A M

FIG. 3

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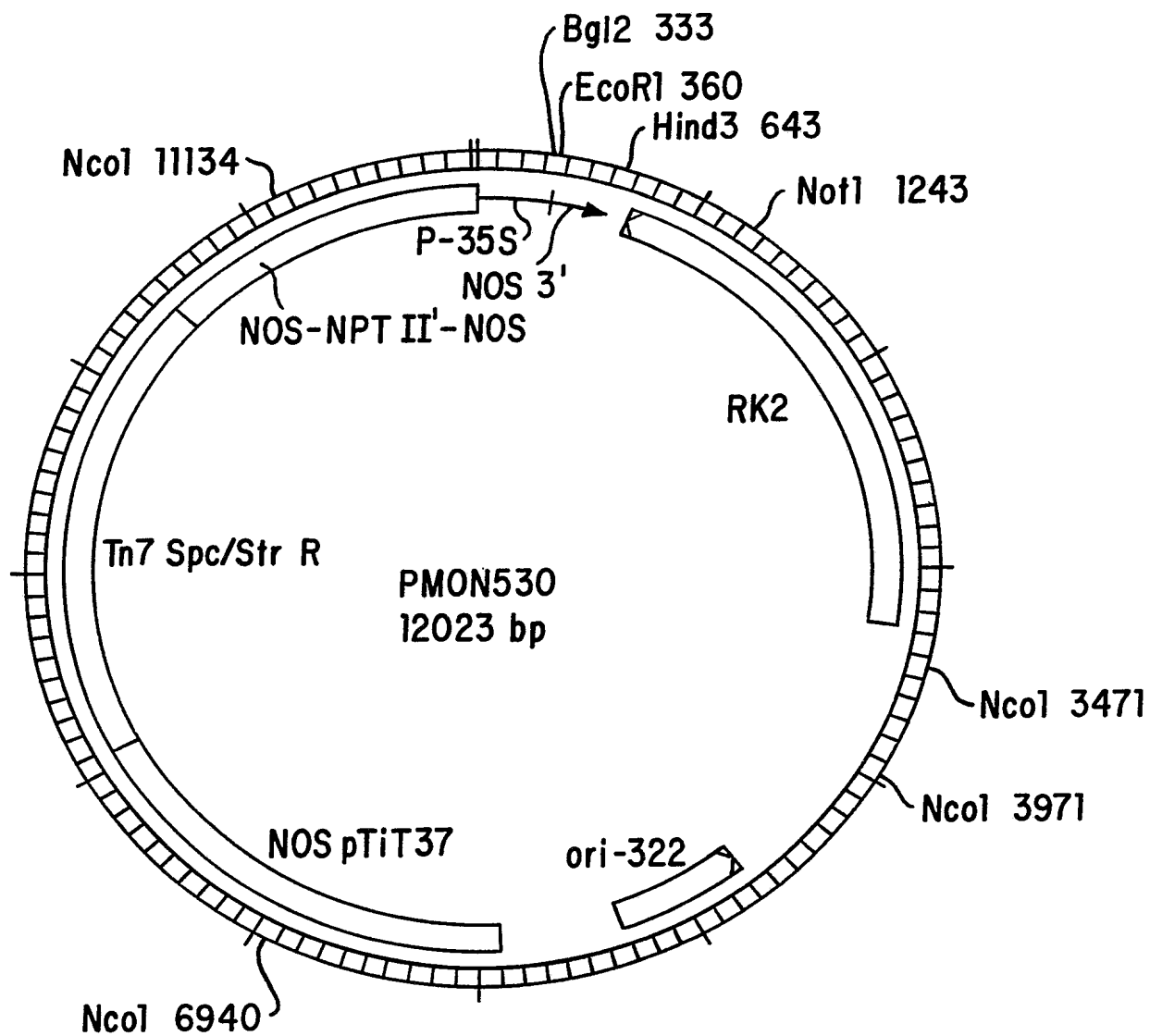


FIG. 4

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1 CCATGGCGGCTTCCATTGGAGCCTTAAAATCTTCACCTTCTTCTAACAATTGCATCAATG 60
MetAlaAlaSerIleGlyAlaLeuLysSerSerProSerSerAsnAsnCysIleAsnG
61 AGAGAAGAAATGATTCTACACGTGCTGTATCCAGCAGAAATCTCTCATTTTCGTCTTCTC 120
luArgArgAsnAspSerThrArgAlaValSerSerArgAsnLeuSerPheSerSerSerH
121 ATCTCGCCGGAGACAAGTTGATGCCTGTATCGTCCTTACGTTCCCAAGGAGTCCGATTCA 180
isLeuAlaGlyAspLysLeuMetProValSerSerLeuArgSerGlnGlyValArgPheA
181 ATGTGAGAAGAAGTCCAATGATTGTGTCGCCAAAGGCTGTTTCTGATTTCGAGAATTCAC 240
snValArgArgSerProMetIleValSerProLysAlaValSerAspSerGlnAsnSerG
241 AGACATGTCTAGACCCAGATGCTAGCCGGAGTGTTTTGGGAATTATTCTTGGAGGTGGAG 300
lnThrCysLeuAspProAspAlaSerArgSerValLeuGlyIleIleLeuGlyGlyGlyA
301 CTGGGACCCGACTTTATCCTCTAACTAAAAAAGAGCAAAGCCAGCTGTTCCACTTGGAG 360
laGlyThrArgLeuTyrProLeuThrLysLysArgAlaLysProAlaValProLeuGlyA
361 CAAATTATCGTCTGATTGACATTCCTGTAAGCAACTGCTTGAACAGTAATATATCCAAGA 420
laAsnTyrArgLeuIleAspIleProValSerAsnCysLeuAsnSerAsnIleSerLysI
421 TTTATGTTCTCACACAATTCAACTCTGCCTCTCTGAATCGCCACCTTTCACGAGCATATG 480
leTyrValLeuThrGlnPheAsnSerAlaSerLeuAsnArgHisLeuSerArgAlaTyrA
481 CTAGCAACATGGGAGGATACAAAACGAGGGCTTTGTGGAAGTTCTTGCTGCTCAACAAA 540
laSerAsnMetGlyGlyTyrLysAsnGluGlyPheValGluValLeuAlaAlaGlnGlnS
541 GTCCAGAGAACCCCGATTGGTTCCAGGGCACGGCTGATGCTGTCAGACAATATCTGTGGT 600
erProGluAsnProAspTrpPheGlnGlyThrAlaAspAlaValArgGlnTyrLeuTrpL
601 TGTTTGAGGAGCATACTGTTCTTGAATACCTTATACTTGCTGGAGATCATCTGTATCGAA 660
euPheGluGluHisThrValLeuGluTyrLeuIleLeuAlaGlyAspHisLeuTyrArgM
661 TGGATTATGAAAAGTTTATTCAAGCCACAGAGAAACAGATGCTGATATTACCGTTGCCG 720
etAspTyrGluLysPheIleGlnAlaHisArgGluThrAspAlaAspIleThrValAlaA
721 CACTGCCAATGGACGAGAAGCGTGCCACTGCATTCCGGTCTCATGAAGATTGACGAAGAAG 780
laLeuProMetAspGluLysArgAlaThrAlaPheGlyLeuMetLysIleAspGluGluG
781 GACGCATTATTGAATTTGCAGAGAAACCGCAAGGAGAGCAATTGCAAGCAATGAAAGTGG 840
lyArgIleIleGluPheAlaGluLysProGlnGlyGluGlnLeuGlnAlaMetLysValA

FIG.5A

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841 ATACTACCATTTTAGGTCTTGATGACAAGAGAGCTAAAGAAATGCCTTTCATTGCCAGTA 900
spThrThrIleLeuGlyLeuAspAspLysArgAlaLysGluMetProPheIleAlaSerM
901 TGGGTATATATGTCATTAGCAAAGACGTGATGTTAAACCTACTTCGTGACAAGTTCCTG 960
etGlyIleTyrValIleSerLysAspValMetLeuAsnLeuLeuArgAspLysPheProG
961 GGGCCAATGATTTTGGTAGTGAAGTTATTCCTGGTGCACTTCACTTGGGATGAGAGTGC 1020
lyAlaAsnAspPheGlySerGluValIleProGlyAlaThrSerLeuGlyMetArgValG
1021 AAGCTTATTTATATGATGGGTACTGGGAAGATATTGGTACCATTGAAGCTTCTACAATG 1080
lnAlaTyrLeuTyrAspGlyTyrTrpGluAspIleGlyThrIleGluAlaPheTyrAsnA
1081 CCAATTTGGGCATTACAAAAAGCCGGTGCCAGATTTTAGCTTTTACGACCGATCAGCCC 1140
laAsnLeuGlyIleThrLysLysProValProAspPheSerPheTyrAspArgSerAlaP
1141 CAATCTACACCAACCTCGATATCTACCACCATCAAAAATGCTTGATGCTGATGTCACAG 1200
roIleTyrThrGlnProArgTyrLeuProProSerLysMetLeuAspAlaAspValThrA
1201 ATAGTGTCAATTGGTGAAGGTTGTGTGATCAAGAACTGTAAGATTCATCATTCCGTGGTTG 1260
spSerValIleGlyGluGlyCysValIleLysAsnCysLysIleHisHisSerValValG
1261 GACTCAGATCATGCATATCAGAGGGAGCAATTATAGAAGACTCACTTTTGATGGGGGCAG 1320
lyLeuArgSerCysIleSerGluGlyAlaIleIleGluAspSerLeuLeuMetGlyAlaA
1321 ATTACTATGAGACTGATGCTGACAGGAAGTTGCTGGCTGCAAAGGGCAGTGCCCAATTG 1380
spTyrTyrGluThrAspAlaAspArgLysLeuLeuAlaAlaLysGlySerValProIleG
1381 GCATCGGCAAGAATTGTCACATTAAGAGAGCCATTATCGACAAGAATGCCCGTATAGGGG 1440
lyIleGlyLysAsnCysHisIleLysArgAlaIleIleAspLysAsnAlaArgIleGlyA
1441 ACAATGTGAAGATCATTAACAAAGACAACGTTCAAGAAGCGGCTAGGGAAACAGATGGAT 1500
spAsnValLysIleIleAsnLysAspAsnValGlnGluAlaAlaArgGluThrAspGlyT
1501 ACTTCATCAAGAGTGGGATTGTCACCGTCATCAAGGATGCTTTGATTCCAAGTGGAAATCA 1560
yrPheIleLysSerGlyIleValThrValIleLysAspAlaLeuIleProSerGlyIleI
1561 TCATCTGATGAGCTC 1575
leIleEndEnd

FIG.5B

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1	AACAAGATCAAACCTGGGGTTGCTTACTCTGTGATCACTACTGAAAATGACACACAGACT	60
	AsnLysIleLysProGlyValAlaTyrSerValIleThrThrGluAsnAspThrGlnThr	
61	GTGTTTCGTAGATATGCCACGTCTTGAGAGACGCCGGGCAAATCCAAAGGATGTGGCTGCA	120
	ValPheValAspMetProArgLeuGluArgArgArgAlaAsnProLysAspValAlaAla	
121	GTCATACTGGGAGGAGGAGAAGGGACCAAGTTATCCCACTTACAAGTAGAACTGCAACC	180
	ValIleLeuGlyGlyGlyGluGlyThrLysLeuPheProLeuThrSerArgThrAlaThr	
181	CCTGCTGTTCCGGTTGGAGGATGCTACAGGCTAATAGACATCCCAATGAGCAACTGTATC	240
	ProAlaValProValGlyGlyCysTyrArgLeuIleAspIleProMetSerAsnCysIle	
241	AACAGTGCTATTAACAAGATTTTTGTGCTGACACAGTACAATTCTGCTCCCTGAATCGT	300
	AsnSerAlaIleAsnLysIlePheValLeuThrGlnTyrAsnSerAlaProLeuAsnArg	
301	CACATTGCTCGAACATATTTTGGCAATGGTGTGAGCTTTGGAGATGGATTTGTCGAGGTA	360
	HisIleAlaArgThrTyrPheGlyAsnGlyValSerPheGlyAspGlyPheValGluVal	
361	CTAGCTGCAACTCAGACACCCGGGGAAGCAGGAAAAAATGGTTTCAAGGAACAGCAGAT	420
	LeuAlaAlaThrGlnThrProGlyGluAlaGlyLysLysTrpPheGlnGlyThrAlaAsp	
421	GCTGTTAGAAAATTTATATGGGTTTTTGAGGACGCTAAGAACAAGAATATTGAAAATATC	480
	AlaValArgLysPheIleTrpValPheGluAspAlaLysAsnLysAsnIleGluAsnIle	
481	GTTGTACTATCTGGGGATCATCTTTATAGGATGGATTATATGGAGTTGGTGCAGAACCAT	540
	ValValLeuSerGlyAspHisLeuTyrArgMetAspTyrMetGluLeuValGlnAsnHis	
541	ATTGACAGGAATGCTGATATTACTCTTTCATGTGCACCAGCTGAGGACAGCCGAGCATCA	600
	IleAspArgAsnAlaAspIleThrLeuSerCysAlaProAlaGluAspSerArgAlaSer	
601	GATTTTGGGCTGGTCAAGATTGACAGCAGAGGCAGAGTAGTCCAGTTTGCTGAAAAACCA	660
	AspPheGlyLeuValLysIleAspSerArgGlyArgValValGlnPheAlaGluLysPro	
661	AAAGGTTTTGATCTTAAAGCAATGCAAGTAGATACTACTCTTGTTGGATTATCTCCACAA	720
	LysGlyPheAspLeuLysAlaMetGlnValAspThrThrLeuValGlyLeuSerProGln	

FIG.6A

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721 GATGCGAAGAAATCCCCCTATATTGCTTCAATGGGAGTTTATGTATTCAAGACAGATGTA 780
AspAlaLysLysSerProTyrIleAlaSerMetGlyValTyrValPheLysThrAspVal
781 TTGTTGAAGCTCTTGAAATGGAGCTATCCCACTTCTAATGATTTTGGCTCTGAAATTATA 840
LeuLeuLysLeuLeuLysTrpSerTyrProThrSerAsnAspPheGlySerGluIleIle
841 CCAGCAGCTATTGACGATTACAATGTCCAAGCATACATTTTCAAAGACTATTGGGAAGAC 900
ProAlaAlaIleAspAspTyrAsnValGlnAlaTyrIlePheLysAspTyrTrpGluAsp
901 ATTGGAACAATTAATCGTTTTATAATGCTAGCTTGGCACTCACACAAGAGTTTCCAGAG 960
IleGlyThrIleLysSerPheTyrAsnAlaSerLeuAlaLeuThrGlnGluPheProGlu
961 TTCCAATTTTACGATCCAAAAACACCTTTTACACATCTCCTAGGTTTCTTCCACCAACC 1020
PheGlnPheTyrAspProLysThrProPheTyrThrSerProArgPheLeuProProThr
1021 AAGATAGACAATTGCAAGATTAAGGATGCCATAATCTCTCATGGATGTTTCTTGCGAGAT 1080
LysIleAspAsnCysLysIleLysAspAlaIleIleSerHisGlyCysPheLeuArgAsp
1081 TGTTCTGTGGAACACTCCATAGTGGGTGAAAGATCGCGCTTAGATTGTGGTGTGAACTG 1140
CysSerValGluHisSerIleValGlyGluArgSerArgLeuAspCysGlyValGluLeu
1141 AAGGATACTTTTCATGATGGGAGCAGACTACTACCAAACAGAATCTGAGATTGCCTCCCTG 1200
LysAspThrPheMetMetGlyAlaAspTyrTyrGlnThrGluSerGluIleAlaSerLeu
1201 TTAGCAGAGGGGAAAGTACCGATTGGAATTGGGGAAAATACAAAATAAGGAAATGTATC 1260
LeuAlaGluGlyLysValProIleGlyIleGlyGluAsnThrLysIleArgLysCysIle
1261 ATTGACAAGAACGCAAAGATAGGAAGAATGTTTCAATCATAAATAAGACGGTGTTCAA 1320
IleAspLysAsnAlaLysIleGlyLysAsnValSerIleIleAsnLysAspGlyValGln
1321 GAGGCAGACCGACCAGAGGAAGGATTCTACATACGATCAGGGATAATCATTATATTAGAG 1380
GluAlaAspArgProGluGluGlyPheTyrIleArgSerGlyIleIleIleIleLeuGlu
1381 AAAGCCACAATTAGAGATGGAACAGTCATCTGAAGTAGGGAAGCACCTCTTGTTGAACTA 1440
LysAlaThrIleArgAspGlyThrValIleEnd
1441 CTGGAGATCCAAATCTCAACTTGAAGAAGGTCAAGGGTGATCCTAGCACGTTACCAGTT 1500
1501 GACTCCCCGAAGGAAGCTT 1519

FIG.6B

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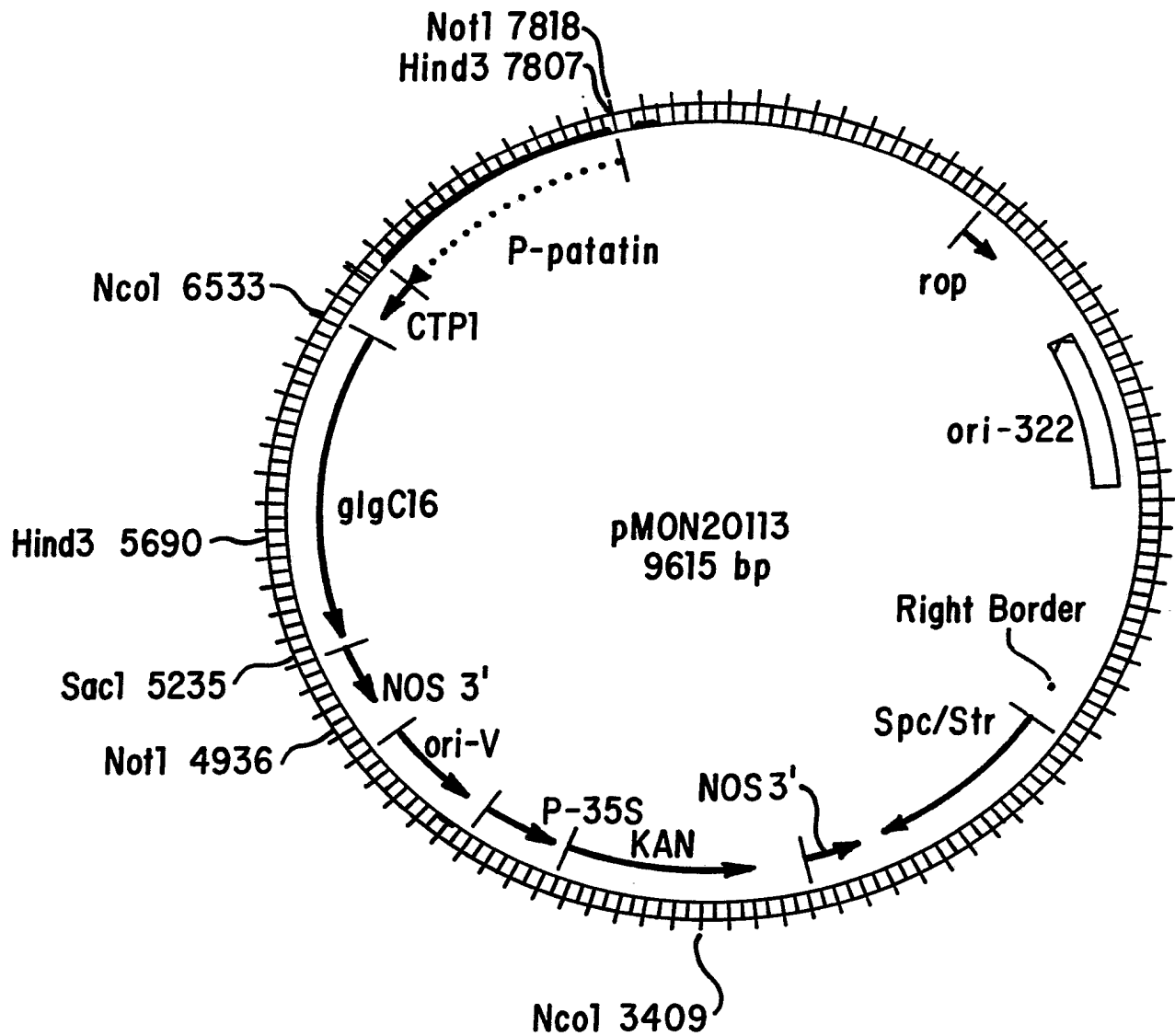


FIG. 7

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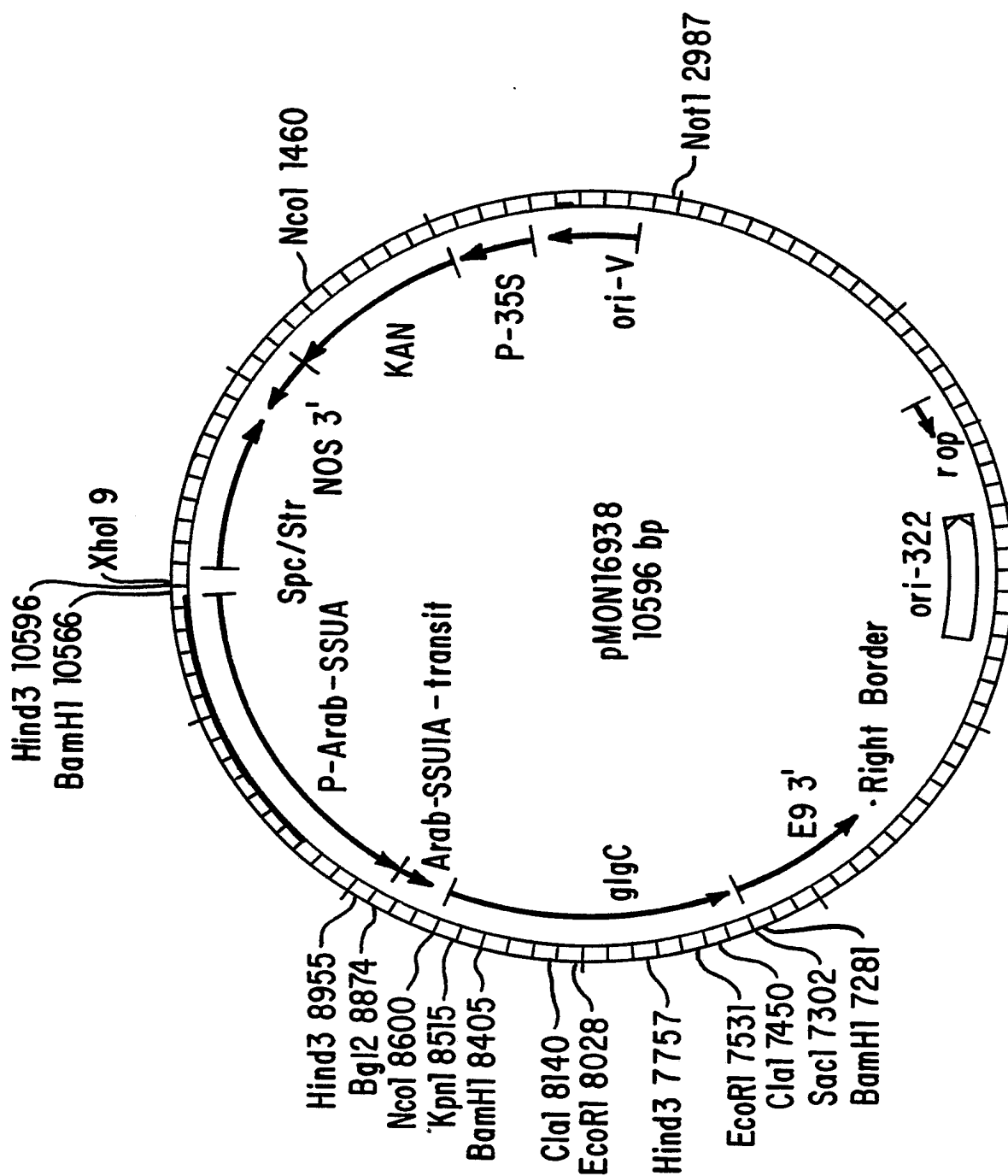
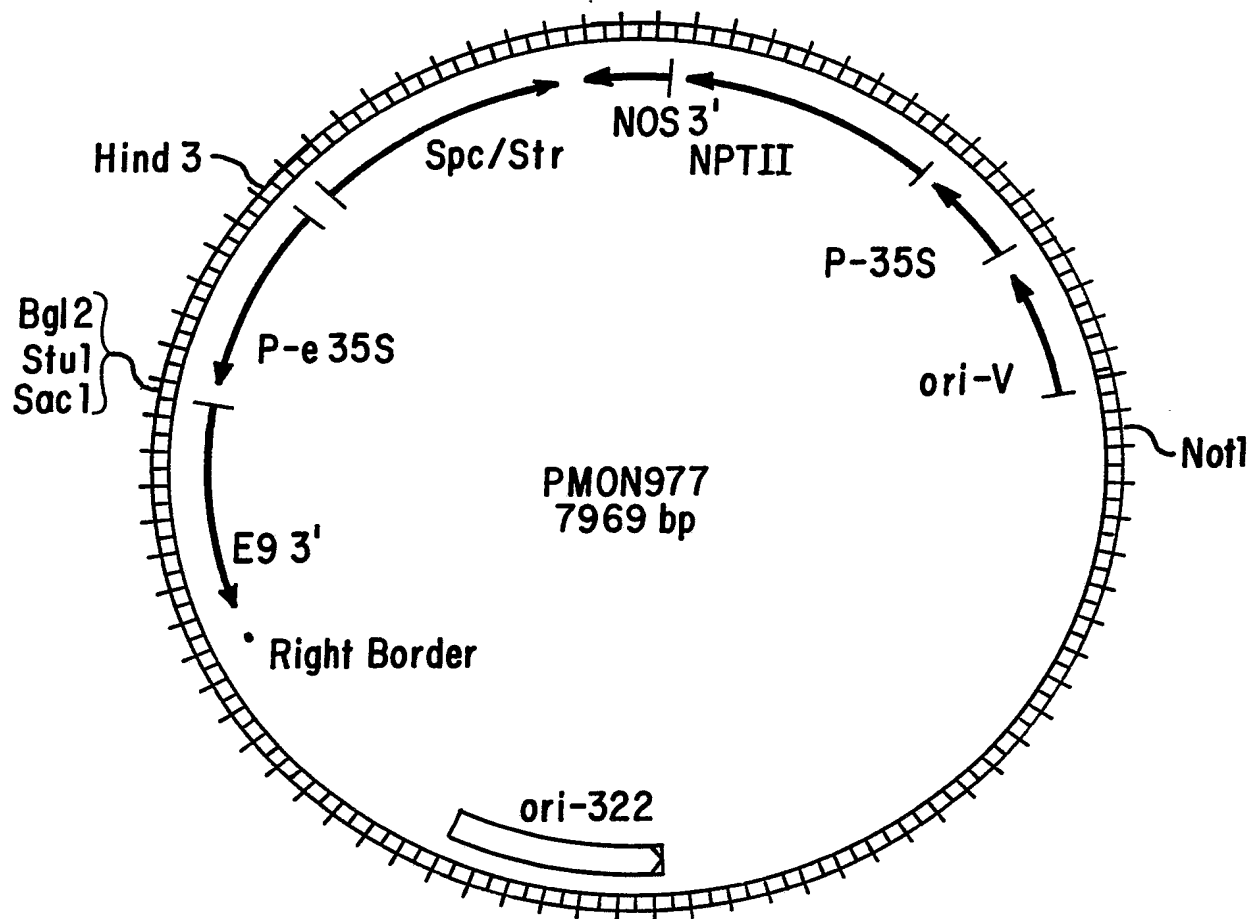


FIG. 8

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-FIG. 9

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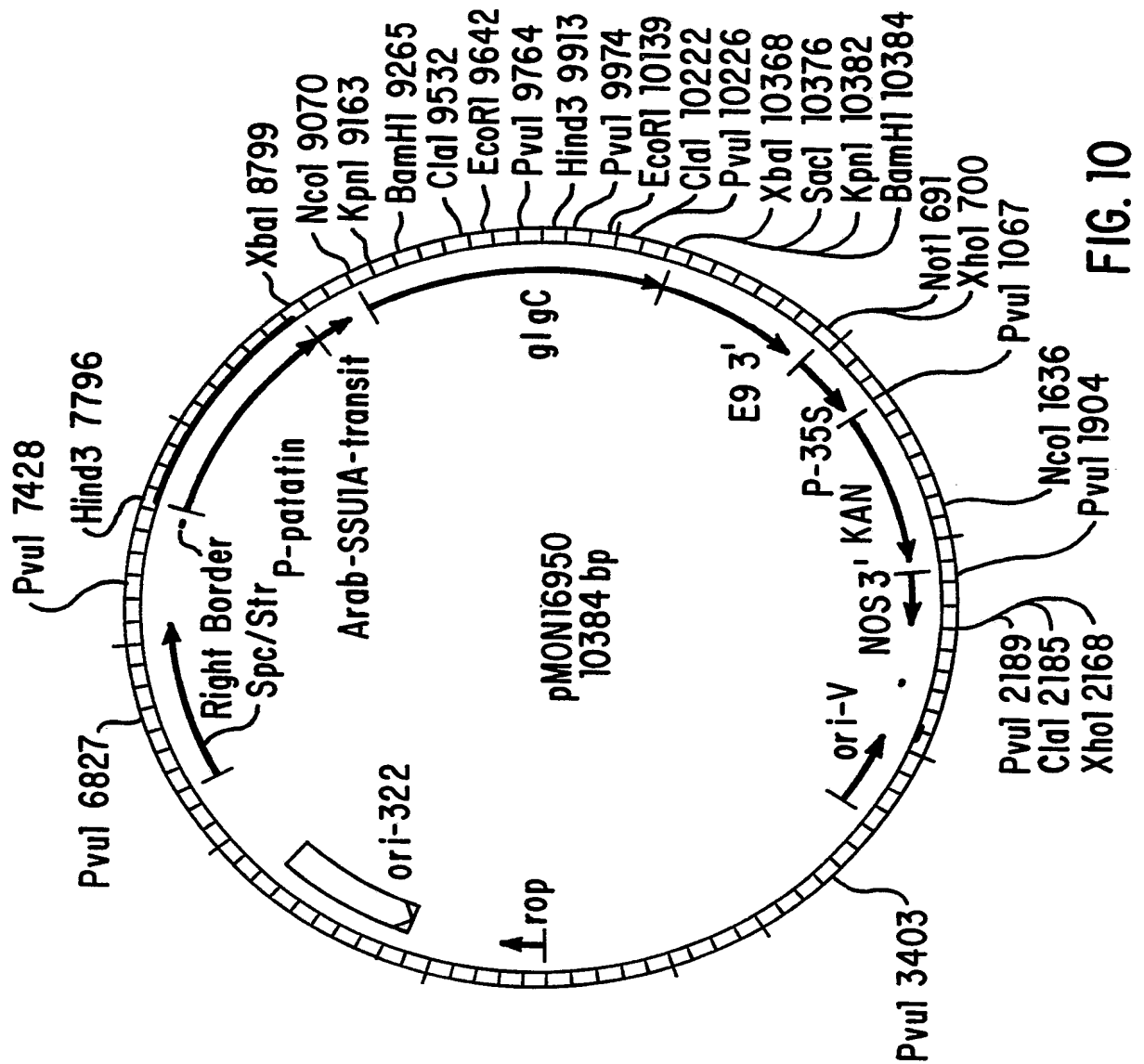


FIG. 10

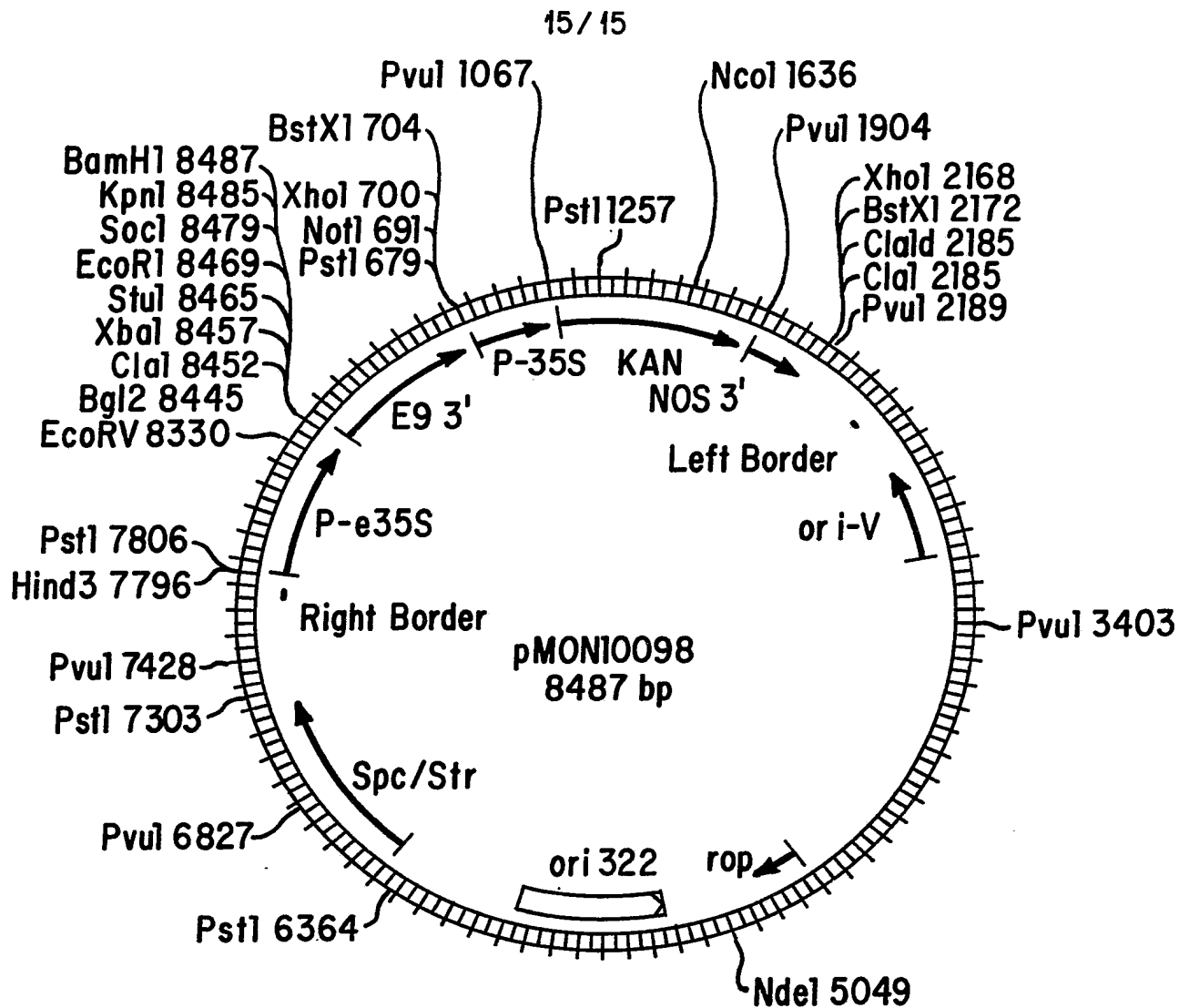



FIG. 11

INTERNATIONAL SEARCH REPORT

PCT/US 91/04036

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl. 5 C12N15/82 ; C12N15/54 ; C12N5/10 ; A01H5/00		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	C12N ; A01H	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claims No. ¹³
X	EP,A,368 506 (ICI) May 16, 1990 see column 4, line 21 - line 58; claim 13 ---	1,2,5,6, 10,15, 16,18
X	PLANT PHYSIOL vol. 89, 1989, pages 225 - 230; FREDEEN, A. L., ET. AL.: 'Influence of phosphorous nutrition on growth and carbon partitioning in Glycine max ' see page 227, left column see page 229, right column --- -/--	1
<p>¹⁰ Special categories of cited documents : ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
15 OCTOBER 1991	24 OCT 1991	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	MADDOX A.D. 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	<p>PLANT PHYSIOL vol. 57, 1976, pages 63 - 68; SOWOKINOS, J.R., ET. AL.: 'Pyrophosphorylases in Solanum tuberosum. I. Changes in ADPglucose and UDPglucose pyrophosphorylase activities associated with starch biosynthesis during tuberization, maturation, and storage of potatoes ' see the whole document ---</p>	1
A	<p>ANN. REV. PLANT PHYSIOL. vol. 33, 1982, pages 431 - 454; PREISS: 'Regulation of the biosynthesis and degradation of starch ' see page 431 - page 436 ---</p>	1
P,A	<p>MOL.GEN.GENET. vol. 224, October 1990, pages 136 - 146; MUELLER-ROEBER, B. T.: 'One of two different ADP -glucose pyrophosphorylase genes from potato responds strongly to elevated levels of sucrose ' see page 143, right column - page 145, left column ---</p>	1
P,A	<p>THE PLANT CELL vol. 3, no. 3, March 1991, pages 213 - 218; DILWORTH, M. F.: 'Molecular biology comes home ' see page 216, right column, last paragraph - page 217, left column, paragraph 1 ---</p>	1
P,A	<p>PLANT MOL. BIOL. vol. 16, 1991, pages 349 - 351; DU JARDIN, P., ET.AL.: 'Isolation and sequence analysis of a cDNA clone encoding a subunit of the ADP - glucose pyrophosphorylase of potato tuber amyloplasts ' see page 349, left column, line 1 - line 5 ---</p>	1
A	<p>WO,A,8 802 402 (CALGENE) April 7, 1988 see page 4, line 1 - line 23 --- -/--</p>	1

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	TAILORING GENES FOR CROP IMPROVEMENT 1987, ED. G BREUNING pages 133 - 152; PREISS J., ET. AL.: 'Regulation of starch synthesis: enzymological and genetic studies ' see page 134, paragraph 3 ---	1
E	EP, A, 438 904 (ADVANCED TECHNOLOGIES) July 31, 1991 see claims 1, 7, 9-16; figure 1 ---	1, 2, 5, 6, 10, 15, 16, 21-30 35-38

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 9104036
SA 49405

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15/10/91

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EP-A-368506	16-05-90	AU-A- 4430789 JP-A- 2273177	16-08-90 07-11-90
WO-A-8802402	07-04-88	AU-A- 8079787 EP-A- 0285646 JP-T- 1501038	21-04-88 12-10-88 13-04-89
EP-A-438904	31-07-91	AU-A- 6836590	04-07-91